

Science for Peace and Progress

Life and Work of Abdus Salam

Compiled, Edited, Introduced by

Anwar Dil

Foreword by

Professor Riazuddin

National Centre for Physics, Islamabad

Afterword by

Professor Katepalli R. Sreenivasan

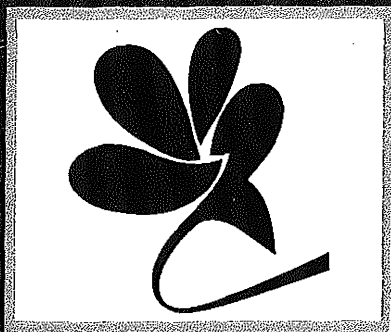
Director, The Abdus Salam International Centre
for Theoretical Physics (ICTP), Trieste, Italy



another publication
Intercultural Forum
Takshila Research University

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Dedicated to
Abdus Salam's inspirational role model
Muhammad Iqbal (1877-1938),
the transformational thinker
whose vision of human excellence
remained a guiding light all his life

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— Anwar Dil

Contents

Dedication	5
Acknowledgments	6
List of Illustrations	15
Abdus Salam: A Biographical Profile	17
Foreword by Dr. Riazuddin	
Distinguished National Professor; Director General, National Centre for Physics, Quaid-i-Azam University, Islamabad	25
Life and Work of Abdus Salaam:	
An Introductory Essay by Anwar Dil	29
 PART I. SELECTED WRITINGS BY ABDUS SALAM	 75
1. My Concept of Successful Life (1958)	77
2. Technology and Pakistan's Attack on Poverty (1961)	78
3. Need for an International Centre for Theoretical Physics (1962)	87
4. Diseases of the Rich and Diseases of the Poor (1963)	91
5. Pakistan and Technical Development (1964)	94
6. Mathematics in Science – A Poetic Language (1964)	101
7. The Less Developed World: How Can We Be Optimists? (1964)	104
8. Iqbal Memorial Lectures: Symmetry Concepts in Modern Physics (1965)	106
9. A New Centre for Physics (1965)	127
10. The Isolation of the Scientist in Developing Countries (1966)	132
11. Some Thoughts on the Role of Science and Technology (1966)	137
12. The Advancement of Science for the Developing Countries (1967)	140
13. The Permanently Rich and Permanently Poor (1967)	152
14. Memorandum on a World University (1970)	156
15. Memorandum on Islamic Science Foundation (1973)	159
16. The United Nations University (1973)	163
17. A World Federation of Institutes of Advanced Study (1973)	166
18. Ideals and Realities (1976)	172
19. Nobel Prize for Physics 1979: Excerpt from the Nobel Lecture, Nobel Award, Remarks at the Nobel Banquet 1979)	183

20. Islamabad Lecture (1979)	193
21. Einstein's Last Dream: The Space-Time Unification of Fundamental Forces (1979)	199
22. The Nature of the "Ultimate" Explanation in Physics (1979)	207
23. Expatriate Nationals and Promotion of Education and Research in Developing Countries (1982)	214
24. The Fusion of Cultures in Spain (1983)	221
25. The Gulf University and Science in the Arab-Islamic Commonwealth (1983)	226
26. International Commons: Sharing of International Resources (1983)	248
27. Beam Weapons in Space (1984)	258
28. The Role of Science in International Development (1985)	266
29. Physics and the Excellence of Life it Brings (1985)	273
30. Nuclear Security, Disarmament and Development (1985)	284
31. Science and Peace (1985)	294
32. Drought, Desertification and Food Deficit Study Project (1986)	299
33. Highlights of Science for Turkey (1986)	302
34. The Ultimate Nuclear Accident (1987)	313
35. A "Silent Genocide" (1988)	319
36. Scientific Thinking between the Secularization and the Transcendent: An Islamic Viewpoint (1988)	322
37. Notes on Science and Higher Technology and Development for Iran and the Islamic Countries (1988)	334
38. Science in the Third World (1989)	361
39. Maimonides' Scientific Contribution in Relation to the Milieu of Science in Islam (1990)	364
40. A.D. Sakharov: He Was a Legend in His Own Day (1991)	369
41. Excerpts from <i>Science and Technology: Challenge for the South</i> (1992)	371
42. Cooperation for Development in the Third World (1994)	389

PART II. TRIBUTES AND REMINISCENCES

43. A Pakistani Physicist Makes His Outstanding Contribution by Special Correspondent, <i>The Pakistan Times</i> , Lahore (1957)	397
44. The Lonely Physicists by <i>International Science and Technology</i> (1964)	403
45. A Man of Science by Nigel Calder (1967)	409
46. "Sanad" by King Hassan II of Morocco (1980)	417
47. Professor Abdus Salam by Professor John Ziman (1981)	420

48. The Blindness of the Third World by Denzil Peiris (1981)	425
49. A Genius Called Abdus Salam by V.S. Venkatavaradan (1981)	432
50. The Physicists that Changed the World: The Young Masters: Abdus Salam by C.P. Snow (1982)	437
51. How I Discovered SU(3) by Dr. Yuval Ne'eman	439
52. Abdus Salam by Rushworth M. Kidder (1986)	441
53. A Review of the Italian Edition of Abdus Salam's <i>Ideal and Realities</i> (1986)	446
54. Introduction to Abdus Salam's <i>A Renaissance of Sciences in Islamic Countries</i> by Dr. M.H.A. Hassan and Dr. Hassan Dalafi (1988)	447
55. Science Sublime: Abdus Salam, Theoretical Physicist by Dr. Lewis Wolpert and Dr. Alison Richards (1988)	453
56. Grand Unification: A Tribute to Abdus Salam by Dr. Fred Reines (1989)	461
57. Physics for the Poor by <i>The Economist</i> (1989)	462
58. A Unifying Force for Third World Science by Nina Hall (1990)	465
59. The Cambridge Days by Professor Nicholas Kemmer (1990)	468
60. Excerpts from Selected Tributes to Dr. Abdus Salam on his 65th Birthday, Trieste, January 29, 1991	472
60.1 Professor P. Budinich, Former Deputy Director of ICTP	472
60.2 Dr. Hans Blix, International Atomic Energy Agency	473
60.3 Professor L. Bertocchi, Deputy Director, ICTP	473
60.4 Professor G. Salvini, President, Accademia dei Lincei, Rome	475
60.5 Prof. M.H.A. Hassan, Executive Secretary, Third World Academy of Sciences	476
60.6 Ambassador Augustin Papic, Former Member of the South Commission	479
60.7 Prof. A. Tavkhelidze, President, Academy of Sciences of Georgian SSR.	481
60.8 Prof. Yu Lu, Condensed Matter Research Group, ICTP	482
60.9 Response by Dr. Abdus Salam	484
61. <i>Excerpts from Selected Messages to Dr. Abdus Salam on his 65th Birthday, Trieste, January 29, 1991</i>	488
61.1 Dr. Frank Press, President, National Academy of Sciences	488

61.2 Prof. Zhou Guangzhao, President, Chinese Academy of Sciences	488
61.3 Munir Ahmad Khan, President, Pakistan Atomic Energy Commission, Islamabad	488
61.4 Dr. Michael Atiyah, President, The Royal Society, London	489
61.5 Profs. A. Tavkhelidze, V. Mateev, V. Rubakov, M.A. Markov, The Academy of Sciences of the USSR	489
61.6 Dr. Sigvard Eklund, International Atomic Energy Agency, Vienna	489
61.7 Professor A. Berbich, Permanent Secretary, Academy of the Kingdom of Morocco, Rabat	489
62. From "A Life of Physics" by Jagjit Singh (1992)	491
63. Excerpts from Selected Lectures in "Salamfestschrift" (1993)	495
63.1 Dr. Ahmed Ali, DESI, Hamburg, Germany	495
63.2 Dr. Steven Weinberg, University of Texas, Austin	495
63.3 Dr. A. Zichichi, CERN, Geneva	496
63.4 Dr. Robert Delbourgo, University of Tasmania, Australia	497
63.5 Dr. Jogesh C. Pati, University of Maryland, USA	498
63.6 Dr. Peter West, King's College, London	499
63.7 Dr. Ergin Sezgin, Texas A&M University, USA	499
63.8 Dr. Gerhard Mack, Universität Hamburg, Germany	500
63.9 Dr. M.J. Duff, Texas A&M University, USA	011
63.10 Dr. T.W.B. Kibble, Imperial College, London	502
64. Abdus Salam and the Shaping of Science by <i>Nature</i> (1995)	506
65. Professor Salam's Contribution in the Development of Science and Technology in Pakistan by Dr. Ishfaq Ahmad, Islamabad	509
66. Abdus Salam, Lone Pakistani Nobel Laureate, Turns Seventy by Dr. Anis Alam, Lahore	513
67. <i>Some Condolence Messages from ICTP Files on Dr. Abdus Salam's Death, November 21, 1996</i>	518
67.1 Dr. Hans Blix, Director General, IAEA	518
67.2 Dr. Federico Mayor, Director General, UNESCO	518
67.3 Dr. Zhou Guangzhao, President, Chinese Academy of Sciences	518
67.4 Dr. R. Amrollahi, President, Atomic Energy Organization of Iran	518
67.5 Sir Arthur C. Clarke, Sri Lanka	519

67.6 Dr. Ayhan O. Cavdar, President, Turkish Academy of Sciences	519
67.7 Julius Nyerere, Former President of Tanzania, President, South Centre	519
67.8 Dr. M.J.A. Larijani, Director, Institute for Studies in Theoretical Physics and Mathematics, Iran	519
67.9 Dr.G. Thyagarajan, President, International Council of Scientific Unions, India	519
67.10 Dr. Fawzi Gharaibeh, President, University of Jordan	520
67.11 Dr. Dhruba Man Singh, Vice Chancellor, Royal Nepal Academy of Science and Technology	520
67.12 Dr. Heitor Gurgulino de Souza, Rector, United Nations University, Tokyo	520
67.13 Dr. Salha Sankar, Minister of Higher Education, Syria	520
67.14 Dr. Ruth Zagorin-Hopper, Chairman, The International Federation of Institutes for Advanced Study, Canada	521
67.15 Dr. Thomas RR. Odhiambo, Director, The International Centre of Insect Physiology and Ecology, Kenya	521
67.16 Dr. Victor Latorre, Director of Multiciencias, Peru	521
67.17 Dr. Rohan H. Wickramasinghe, Director, Institute of Tropical Environmental Studies, Sri Lanka	522
67.18 Dr. Asghar Qadir, Pakistan	522
67.19 Dr. M.S. Swaminathan, India	522
67.20 Dr. R. Ramachandran, ⁴ Director, The Institute of Mathematical Sciences, Chennai, India	522
67.21 Dr. Galileo Violini, Director, Comisión Europa, San Salvador	523
67.22 Dr. Tchavdar Palev, Bulgarian Academy of Sciences	523
67.23 Dr. D.A. Akveampong, University of Ghana	523
67.24 Dr. Sing Lees, University of Malaya	523
68. <i>Excerpts from Selected Obituary Articles on Abdus Salam (1926-1996)</i>	524
68.1 A Hero is Gone by Dr. Pervez Hoodbhoy, Pakistan (1996)	524
68.2 Abdus Salam – The Human Side by Dr. Mujahid Kamran, Pakistan (1996)	525
68.3 A Torch of Light by Dr. Zafar H. Zaidi, Pakistan (1996)	526
68.4 A Man of Remarkable Vision, <i>The Times</i> , London (1996)	526
68.5 Professor Abdus Salam – Some Reminiscences by Dr. Saeed A. Durrani, Pakistan/UK (1996)	528
68.6 Farewell to Abdus Salam by President Julius K. Nyerere, Tanzania (1996)	531

68.7	Abdus Salam (1926-96) by Dr. Seif Randjbar-Daemi, Iran/Trieste (1996)	532
68.8	A Tribute to Abdus Salam by Dr. M.J. Duff, USA (1996)	534
68.9	Many Salaams to Dr. Salam by Dr. Aftab Ahmed, Pakistan (1996)	537
68.10	Physics with a Purpose by Dr. Ehsan Masood (1996)	538
68.11	Abdus Salam (1926-96) by Dr. Tom Kibble and Dr. Chris Isham, UK (1997)	540
68.12	Abdus Salam by Dr. Jogesh C. Pati, USA/India (1997)	541
68.13	Memories of Abdus Salam by Dr. Sheldon L. Glashow, USA (1997)	542
68.14	The Standard Model, Abdus Salam and CERN by Dr. Carlo Rubbia, CERN, Geneva (1997)	545
69.	<i>Selected Tributes at The Abdus Salam Commemoration Meeting, The Abdus Salam International Centre for Theoretical Physics, November 19-21, 1997</i>	548
69.1	Welcome Address by Dr. Miguel Angel Virasoro	548
69.2	Fulfilled and Not Yet Realized Dream by Dr. Paolo Budinich	552
69.3	My Association with Abdus Salam by Dr. Luciano Bertocchi	554
69.4	From the Advanced School for Physics to the Synchrotron by Dr. Luciano Fonda	557
69.5	Abdus Salam and the Department of Theoretical Physics by Dr. GianCarlo Ghirardi	558
69.6	INFN and the Centre by Dr. Nello Paver	560
69.7	At the Service of a Great Scientist and Administrator by Dr. André-Marie Hamende	562
69.8	Abdus Salam and the Experience of Mystery by Dr. Sergio Fubini	565
69.9	Abdus Salam and Africa by Dr. Daniel Akyeampong, Ghana	566
69.10	Teacher, Colleague and Friend by Dr. Robert Delbourgo, Australia	568
69.11	Fun with Abdus Salam by Dr. Gordon Feldman, USA	571
69.12	What I Learned from Abdus Salam by Dr. Gerhard Mack, Germany	574

- 69.13 Together in Lahore and Cambridge
by Dr. Ram Prakash Bambah, India 575
- 69.14 Delight in Abdus Salam's Company
by Dr. John Ziman, UK 579
- 69.15 Thirty Years of Condensed Matter Physics
by Dr. Stig Lundqvist, Sweden 582
- 69.16 A Lighthouse for Young Scientists
by Dr. Rexhep Meidani, Albania 583
- 69.17 We Shall Maintain the Level of Excellence of the Centre
by Dr. Gioacchino Fonti, Italy 586
- 69.18 A Great International Servant
by Dr. Hans Blix, Sweden 587
- 69.19 Bridging the Gap Between North and South
by Dr. Adnan Badran, Jordan 589
- 69.20 Uniting Third World Scientists and Their Organizations
by Dr. Mohamed H.A. Hassan, Sudan/TWAS 592
- 69.21 Third World Women Scientists
by Dr. Lydia Makhubu, Swaziland 595
- 69.22 Abdus Salam's Cosmic Anger
by Nigel Calder, UK 597
- 69.23 Salam as I Knew Him
by Munir Ahmad Khan, Pakistan 599
- 69.24 Servant of Peace
by Dr. Asghar Qadir, Pakistan 604
- 69.25 Remaining Part of the World of Real Physics
by Dr. Igor Saadedra, Chile 607
- 69.26 Abdus Salam in Peru
by Dr. Victor Latorre, Peru 609
- 69.27 Ideals and Realities: Working with Abdus Salam
by Dr. Sergio Mascarenhas, Brazil 610
- 69.28 Remembering Dr. Abdus Salam
by Dr. Fahim Hussain, Pakistan/ICTP, Trieste 612
70. Professor Abdus Salam: An Epoch-Making Personality
by Dr. Ghulam Murtaza, Pakistan (1997) 614
71. Dr. Abdus Salam Remembered
by Dr. C.H. Llewellyn Smith, CERN, Geneva (1997) 616
72. Abdus Salam
by Dr. Freeman J. Dyson, USA (1999) 618
73. A Great Synthesizer of the Century
by Dr. Abdullah Sadiq, Pakistan (1999) 621

74.	Abdus Salam and Shaping the Destiny of Science and Technology in Developing Countries by Dr. M.S. Swaminathan, India (2007)	623
75.	Abdus Salam – A Passionate Genius by Dr. Atta-ur-Rahman, Pakistan (2008)	625
PART III. ANNEXES		629
Annex I.	Abdus Salam's "Hair and Hair-dressers", <i>The Ravi</i> , Government College, Lahore (1944)	631
Annex II.	Abdus Salam's "The White Arm" (1945)	633
Annex III.	Abdus Salam's "A Visit to Germany" (1948)	635
Annex IV.	Abdus Salam's "Homage to Muhammad Zafrulla Khan" (1986)	640
Annex V.	Abdus Salam's "Poor as a Nation" (1987)	645
Afterword by Dr. Katepalli R. Sreenivasan Abdus Salam Honorary Professor and Executive Director, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy		653
Title Cover Text and Illustrations		658
Index		661

List of Illustrations

[Unless identified otherwise, all photographs are from The Abdus Salam International Centre for Theoretical Physics Library and Intercultural Forum Archives]

1.	"The Flower of Peace" by Anwar Dil, 1986	Front Title Cover,	658
2.	Portrait Abdus Salam	Title Cover Back Inner Flap,	659
3.	Portrait of Anwar Dil	Title Cover Back Inner Flap,	659
4.	Prof. Riazuddin		25
5.	Abdus Salam, 1940		29
6.	Salam, student at Government College, Lahore, 1946		32
7.	Salam, student at Cambridge University, 1948		33
8.	Salam, Professor, Government College, Lahore, 1952		34
9.	Leo Szilard		34
10.	With Prof. P.A.M. Dirac at Cambridge University, 1950		35
11.	Prof. Abdus Salam, Imperial College, London, 1958		35
12.	With I.H. Usmani, Islamabad, 1960		36
13.	Salam's Handwritten Note on ICTP Proposal, 1960		40
14.	With S. Eklund, Director General, IAEA, 1962		40
15.	With S. Eklund, Paolo Budinich at ICTP, 1964		40
16.	With Robert Oppenheimer at ICTP Council meeting, 1965		40
17.	With Italian President Giulio Andreotti, ICTP, 1989		40
18.	In Pakistani dress at the Nobel Prize for Physics ceremony, 1979		42
19.	With Julius Nyerere, Chairman, South Commission, 1989		47
20.	Showing the Nobel Prize award to his children, 1979		57
21.	At the wedding of his son, Ahmad Salam, 1993		57
22.	Salam's second son, Umar Salam, 1997		57
23.	Poet-Philosopher Muhammad Iqbal		73
24.	Portrait of Abdus Salam, 1962		75
25.	Title Covers of Some of Salam's Books		76
26.	With P. Budinich and participants in 1960 Seminar, Miramare		90
27.	Salam at ICTP		103
28.	Sketch of Abdus Salam		136
29.	Norman Borlaug, World Peace Laureate		146
30.	H.M. Beachell, World Food Laureate		146
31.	Sigvard Eklund, Director General IAEA		148
32.	Paolo Budinich, Deputy Director ICTP		149
33.	Lecturing at Public Library, Lahore		162
34.	U Thant, Secretary General, United Nations		165
35.	Andrew Cordier, Chairman, United Nations University Committee		165
36.	1979 Nobel Physics Prize Winners: Glashow, Salam, Weinberg		182
37.	Salam Receiving Nobel Prize from the King of Sweden, 1979		191
38.	Islamic Calligraphic Plaque in Abdus Salam Room, ICTP		192
39.	Islamic Calligraphic Plaque in Abdus Salam Room, ICTP		192
40.	Plaque of the 1979 Nobel Prize for Physics		198
41.	Albert Einstein		206
42.	Herbert Spencer		213
43.	Johannes Kepler		213

44.	Isaac Newton	213
45.	Albert Einstein	213
46.	Werner Heisenberg	213
47.	Stephen Hawking	213
48.	Honorary Degree from Aligarh Muslim University, India, 1981	225
49.	Honorary Degree from Universidad Complutense de Madrid, 1983	225
50.	Galileo	239
51.	With Pope John Paul II in Vatican	239
52.	Richard Feynman	283
53.	Bertrand Russell	293
54.	With UN Secretary-General Javier Pérez de Cuellar, TWAS, 1985	298
55.	Andrei D. Sakharov	370
56.	Sketch of Abdus Salam by Gulgee, 1994	394
57.	Portrait of Salam	395
58.	Titles of Some Edited Books by Abdus Salam	396
59.	Salam's Favorite Calligraphy: "O Lord, Work a Miracle"	416
60.	Abdus Salam	419
61.	King Hassan of Morocco	419
62.	Some Postage Stamps Honoring Abdus Salam	445
63.	Arabic and Urdu Poems in Praise of Abdus Salam	460
64.	Frederick Reines, 1995 Nobel Physics Laureate	461
65.	Aerial View of ICTP Campus, Trieste	464
66.	Main Building of ICTP	464
67.	With Zhou Enlai in Beijing, 1972	467
68.	Prof. Nicholas Kemmer, Salam's Supervisor at Cambridge	468
69.	Titles of Some Books on Abdus Salam	490
70.	Title of <i>The Nucleus: Abdus Salam Issue</i> , Islamabad, 1996	517
71.	Hans Blix, Director General of IAEA	517
72.	Federico Mayor, Director General of UNESCO	517
73.	With Sheldon L. Glashow, 1986	542
74.	Embracing Carlo Rubbia on Winning the Nobel Physics Prize	547
75.	Freeman J. Dyson	617
76.	Some of Abdus Salam Medals	620
77.	With M.S. Swaminathan at Food and Peace Conference, 1994	624
78.	Salam at Government College, Lahore, 1946	625
79.	Government College, Lahore	625
80.	13-year old Salam's Urdu article on Muhammad Iqbal	626
81.	14-year old Salam's Urdu letter to his teacher, 1940	626
82.	Zafrulla Khan, Chief Justice, International Court of Justice	639
83.	Anwar Dil, K.R. Sreenivasan, Afia Dil	652
84.	Anwar Dil Working on Salam Book at ICTP: With K.R. Sreenivasan, M.H.A. Hassan, André-Marie Hamende, Jogesh C. Pati, Abdus Salam Room at ICTP Library	653
85.	Renamed ICTP: The Abdus Salam International Centre for Theoretical Physics, November 21, 1997 –	653

Abdus Salam: A Biographical Profile

- 1926 Born on January 29 at Jhang, Punjab Province, British India
 Father: Chaudhry Muhammad Hussain
 Mother: Hajira Begum
- 1934-38 Educated at M.B.S. Middle School, Jhang (Grades IV-VIII)
- 1938-42 Educated at Government College, Jhang (Classes IX-XII)
- 1942-46 Educated at Government College, Lahore (B.A. and B.A. Honors
 degree in English; M.A. in Mathematics degree 1946)
- 1946-49 Foundation Scholar at St. John's College, Cambridge (B.A. Honors.
 Double First in Mathematics [Wrangler] and Physics)
- 1950 Awarded Smith's Prize for the most outstanding pre-doctoral
 contribution to Physics, University of Cambridge
- 1951 Fellow, Institute of Advanced Study, Princeton University
- 1951-54 Professor and Head of Mathematics Department, Government
 College, Lahore; and University of the Punjab, Lahore
- 1951-56 Elected Fellow, St. John's College, Cambridge University
- 1952 Research at Cavendish Laboratory, Cambridge. (Ph.D. degree in
 Theoretical Physics)
- 1954 Elected Fellow Pakistan Academy of Sciences, Islamabad
- 1954-56 Lecturer, University of Cambridge
- 1955 Scientific Secretary, Conference on Peaceful Uses of Atomic
 Energy, Geneva, Switzerland
- 1957-93 Professor and Head of Theoretical Physics Department, Imperial
 College, University of London
- 1957 D.Sc. Honoris Causa, University of the Punjab, Lahore, Pakistan
- 1958 Hopkins Prize (Cambridge University) for "the most outstanding
 contribution to Physics during 1957-58," Cambridge University
 Adams Prize, Cambridge University
 Scientific Secretary, Geneva Conference on Peaceful Uses of
 Atomic Energy, Geneva, Switzerland
 Member, Atomic Energy Commission of Pakistan (1958-74)

- 1959 Elected Fellow, The Royal Society (London)
 Adviser, National Commission on Education, Pakistan
 Member, National Commission on Science, Pakistan
 Awarded Sitara-i-Imtiaz [Star of Distinction] by President of Pakistan
 Awarded Pride of Performance Medal and Award by President of Pakistan
- 1961 First Recipient of Maxwell Medal and Award, Physical Society, London
 Chief Scientific Adviser to President of Pakistan (1961-74)
 Elected President, Pakistan Association for the Advancement of Science (1961-62)
 Founder Chairman, Pakistan Space and Upper Atmosphere Committee (1961-64)
- 1962 Member, Board of Governors, International Atomic Energy Agency (IAEA), Vienna (1962-63)
- 1963 Member, National Science Council of Pakistan (1963-75)
 Book (Comp.): *Theoretical Physics. Lectures Presented at the Seminar on Theoretical Physics organized by the International Atomic Energy Agency held at the Palazzino Miramare, Trieste, from 16 July to 25 August 1962*, compiled with Introduction by Abdus Salam. Vienna: International Atomic Energy Agency. [Salam's chapter: The Formalism of Life Groups, pp. 173-96.]
- 1964 Founder-Director, International Centre for Theoretical Physics (ICTP), Trieste (1964-93)
 Hughes Medal, Royal Society, London
 Member, United Nations Advisory Committee on Science and Technology (1964-75)
- 1966 Book: *Iqbal Memorial Lectures: Symmetry Concepts in Modern Physics*, ed. by Fayyazuddin and Munir Ahmad Rashid. Lahore: Atomic Energy Centre.
- 1968 Atoms for Peace Medal and Award, Atoms for Peace Foundation, Rockefeller University, New York
- 1970 Elected Fellow, Royal Swedish Academy of Sciences, Stockholm.
 Member, United Nations Panel and Foundation Committee for the United Nations University (1970-73)
 Member, Scientific Council, Stockholm International Peace Research Institute (1970-73)

- Report: *Structural Changes in Pakistan's Educational System*
(Commissioned by the Government of Pakistan, Islamabad)
- 1971 J. Robert Oppenheimer Memorial Medal and Prize, University of Miami
Elected Foreign Member of the American Academy of Arts and Sciences, Washington
Elected Foreign Member of the USSR Academy of Sciences, Moscow
Elected Honorary Life Fellow, St. John's College, Cambridge
D.Sc. (Honoris Causa), University of Edinburgh
Chairman, United Nations Advisory Committee on Science and Technology (1971-72)
Book (Ed.): *Nonpolynomial Lagrangians, Renormalization and Gravity*, ed. by Abdus Salam. New York: Gordon and Breach Science Publishers. [Salam's chapter: Computation of Renormalization Constants, pp. 3-41.]
- 1972 Elected Vice-President, International Union of Pure and Applied Physics (1972-78)
Book (Ed. with E.P. Wigner): *Aspects of Quantum Mechanics*. Cambridge: Cambridge University Press.
- 1973 Member, Board of Governors, Pakistan Science Foundation (1973-77)
- 1976 Guthrie Medal and Prize, Institute of Physics, London
Elected Member, Club of Rome
- 1977 Sir Devaprasad Sarvadhikary Gold Medal, University of Calcutta
- 1978 Matteucci Medal, Accademia Nazionale dei Lincei, Rome
John Torrence Tate Medal, American Institute of Physics
Royal Medal, Royal Society, London
International Prize for Peace and International Understanding, UNESCO Centre, Florence, Italy
- 1979 Nobel Prize for Physics
Einstein Medal, UNESCO, Paris
Honorary Citizen of Trieste, Italy
Shri R. D. Birla Award, Indian Physics Association
Awarded Nishan-e-Imtiaz by President of Pakistan
Elected Foreign Associate, National Academy of Sciences, Washington DC
Elected Foreign Member, Accademia Nazionale dei Lincei, Rome
Elected Foreign Member, Iraqi Academy, Baghdad

- Elected Honorary Fellow, Tata Institute of Fundamental Research, Bombay
 Elected Honorary Member, Korean Physics Society, Seoul
 Elected Foreign Member, Accademia Tiberina, Rome
 D.Sc. (Honoris Causa), University of Trieste, Italy
 D.Sc. (Honoris Causa), University of Islamabad, Pakistan
- 1980 Order of Andres Bello, Venezuela
 Order of Istiqlal, Jordan
 Cavaliere di Gran Croce dell'Ordine al Merito della Repubblica Italiana
 Elected Foreign Member, Academy of the Kingdom of Morocco, Rabat
 Elected Foreign Member, Accademia Nazionale delle Scienze dei XL, Rome
 Elected Member, European Academy of Sciences, Arts and Humanities, Paris
 Elected Associate Member, Joseph Stefan Institute, Ljubljana
 Elected Foreign Fellow, Indian National Science Academy, New Delhi
 Elected Fellow, Bangladesh Academy of Sciences, Dhaka
 D.Sc. (Honoris Causa), Universidad Nacional de Ingenieria, Lima, Peru
 D.Sc. (Honoris Causa), University of San Marcos, Lima, Peru
 D.Sc. (Honoris Causa), National University of San Antonio, Cusco, Peru
 D.Sc. (Honoris Causa), Universidad Simon Bolivar, Caracas, Venezuela
 D.Sc. (Honoris Causa), University of Wroclaw, Poland
 D.Sc. (Honoris Causa), Yarmouk University, Jordan
 D.Sc. (Honoris Causa), University of Istanbul, Turkey
- 1981 Gold Medal for Outstanding Contributions to Physics, Czechoslovak Academy of Sciences, Prague
 Peace Medal, Charles University, Prague
 Diploma of Highest Merit and Honor, Club of Turkish Intellectuals of Istanbul
 Member, United Nations University Advisory Committee (1981-83)
 Council Member, United Nations University for Peace, Costa Rica (1981-86)
 Elected Chairman, UNESCO Advisory Panel on Science and Society
 Elected Member, Pontifical Academy of Sciences, Vatican City
 Elected Corresponding Member, Portuguese Academy of Sciences, Lisbon

- D.Sc. (Honoris Causa), Guru Nanak Dev University, Amritsar, India
 D.Sc. (Honoris Causa), Aligarh Muslim University, Aligarh, India
 D.Sc. (Honoris Causa), Hindu University, Varanasi, India
 D.Sc. (Honoris Causa), University of Chittagong, Bangladesh
 D.Sc. (Honoris Causa), University of Bristol, UK
 D.Sc. (Honoris Causa), University of Maiduguri, Nigeria
- 1982 D.Sc. (Honoris Causa), University of the Philippines, Quezon City
 Biography: *Abdus Salam: A Nobel Laureate from a Muslim Country*,
 by Abdul Ghani. Karachi: Ma'aref Publisher.
- 1983 Lomonosov Gold Medal, USSR Academy of Sciences, Moscow
 Elected Corresponding Member, Yugoslav Academy of
 Sciences and Arts, Zagreb
 The Medal of the City of Paris (Echelon Vermell)
 Founder-President, Third World Academy of Sciences (TWAS),
 Trieste, Italy (1983-94)
 D.Sc. (Honoris Causa), University of Khartoum, Sudan
 D.Sc. (Honoris Causa), Universidad Complutense de Madrid
- 1984 Elected Honorary Fellow, Ghana Academy of Arts and
 Sciences, Accra
 D.Sc. (Honoris Causa), City University of New York
 D.Sc. (Honoris Causa), University of Nairobi, Kenya
 Book: *Ideals and Realities: Selected Essays by Abdus Salam*, ed. by
 Z. Hassan and C.H. Lai. Singapore: World Scientific Publishing
 Company. [Several editions of the book have been published.
 Translated into Arabic, Bengali, Chinese, French, Italian,
 Persian, Punjabi, Romanian, Turkish, Urdu, and some other
 languages.]
- 1985 Elected Honorary Member, Polish Academy of Sciences
 Premio Europeo Umberto Biancomano, Rome, Italy
 D.Sc. (Honoris Causa), Universidad Nacional de Cuyo, Argentina
 D.Sc. (Honoris Causa), Universidad Nacional de la Plata, Argentina
 D.Sc. (Honoris Causa), University of Cambridge
 D.Sc. (Honoris Causa), University of Göteborg, Sweden
- 1986 Planner, Regional Workshop Course in Curriculum Development in
 Physics, Mathematics and Computer Sciences, Kenya
 Dayemi International Peace Award, Bangladesh
 Elected Corresponding Member, Academia de Ciencias
 Medicas, Fisicas y Naturales de Guatemala

- Member, Board of Directors, Beijir Institute of the Royal Swedish Academy of Sciences (1986-89)
 D.Sc. (Honoris Causa), Kliment Ohridski University of Sofia, Bulgaria
 D.Sc. (Honoris Causa), University of Glasgow, UK
 D.Sc. (Honoris Causa), University of Science and Technology, Hefei, China
 D.Sc. (Honoris Causa), The City University, London
- 1987 Member, South Commission [Chairman: Julius Nyerere, Former President of Tanzania] (1987-90)
 Elected Fellow, Pakistan Academy of Medical Sciences
 Appreciation for Over Twenty Years of Loyal Service, International Atomic Energy Agency (IAEA), Vienna
 Honorary Professor, Beijing University
 D.Sc. (Honoris Causa), Punjab University, Chandigarh, India
 D.Sc. (Honoris Causa), Medicina Alternativa, Colombo, Sri Lanka
 D.Sc. (Honoris Causa), National University of Benin
 D.Sc. (Honoris Causa), University of Exeter, UK
 Book: *Science and Education in Pakistan*. Trieste: Third World Academy of Sciences.
 Book: *Science, Education and Development. A Collection of Essays by and about Abdus Salam*. Ljubljana, Yugoslavia: Research Center for Cooperation with Developing Countries. [Translated into French, Italian, Persian, Spanish]
- 1988 First Edinburgh Medal and Prize, Scotland
 "Genoa" International Development of Peoples Prize, Italy
 Elected Honorary Fellow, Indian Academy of Sciences, Bangalore
 Elected Foreign Fellow, African Academy of Sciences
 Elected Distinguished International Fellow of Sigma Xi
 Honorary Knight Commander of the Order of the British Empire
 Founder-President, Third World Network of Scientific Organizations (TWNSO), Trieste (1988-94)
 D.Sc. (Honoris Causa), University of Gent, Belgium
 Book (Ed. with Ergin Sezgin): *Supergravity in Diverse Dimensions. Volumes I and II*. Singapore: World Scientific Publishing Co.
- 1989 Elected Honorary Member, Brazilian Mathematical Society
 Elected Honorary Member, National Academy of Exact, Physical and Natural Sciences, Argentina
 Elected Honorary Member, Nepal Physical Society

- D.Sc. (Honoris Causa), "Creation" International Association of Scientists and Intelligentsia, USSR
 D.Sc. (Honoris Causa), Bendel State University, Ekpoma, Nigeria
 D.Sc. (Honoris Causa), University of Ghana, Ghana
 Book (Ed.): *From a Life of Physics*. Singapore: World Scientific Publishing Co.
 Book (Ed. with Ergin Sezgin): *Supergravities in Diverse Dimensions. Volumes 1 and 2*. Singapore: World Scientific Publishing Co.
 Biography: *The Greats in Science from the Third World: Abdus Salam*, by Azim Kidwai. Trieste, Italy: Third World Academy of Sciences.

- 1990 Copley Medal, Royal Society, London
 Elected Honorary Member, Hungarian Academy of Sciences
 Elected Member, Academia Europaea
 Catalunya International Prize, Spain
 D.Sc. (Honoris Causa), University of Ghana
 Book: *Unification of Fundamental Forces: The First of the 1988 Dirac Memorial Lectures*. Cambridge: Cambridge University Press. [Translated and published in French, Greek, Italian, Japanese, Norwegian, Portuguese, Spanish]
 Biography: *Abdus Salam un Physicien*, by Entretien avec Jacques Vauthier. Paris: Beauchesne Editeur.

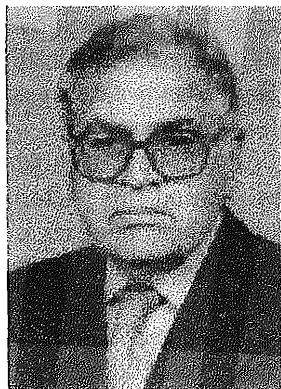
- 1991 Medal of the University of Havana, Cuba
 Elected Honorary Member, Association pro Centro Internacional de Fisica, Bogota, Colombia
 Emeritus Scientist, Centro Brasileiro de Pesquisas Fisicas CBPT, Rio de Janeiro, Brazil
 Honorary Member, Russian Academy of Creative Endeavors
 D.Sc. (Honoris Causa), University of Dakar, Senegal
 D.Sc. (Honoris Causa), University of Warwick, UK
 Book: *Notes on Science, Technology and Science Education in the Development of the South. [Red Book]*. Geneva: United Nations Economic and Social Council and South Commission, July 1991. [Thirteen editions by Abdus Salam. Translated and published in Arabic, Chinese, French, Italian, Persian, Spanish]

- 1992 Gold Medal, Nummum Memoriae Academiae Factum Tribuit, Academia Scientiarum Slovaca, Bratislava, Czechoslovakia
 Elected Foreign Member, American Philosophical Society
 International Leoncino D'Orzo Prize, Italy

- Pesquisador Emerito, Centro Brasileiro de Pesquisas, Rio de Janeiro
 D.Sc. (Honoris Causa), University of Lagos, Nigeria
 D.Sc. (Honoris Causa), University of South Carolina, USA
 D.Sc. (Honoris Causa), University of West Indies, Jamaica
 D.Sc. (Honoris Causa), St. Petersburg University, USSR
 Book: *Science and Technology: Challenge for the South*. Trieste, Italy: International Centre for Theoretical Physics.
 Biography: *Abdus Salam: A Biography*, by Jagjit Singh. New Delhi: Viking Penguin India.
- 1993 International Leoncino d'Oro Prize, Italy
 Elected Fellow, American Physical Society
 Honorary Member, Academia Nacional de Ciencia y Tecnologia, Peru
 Senior Research Fellow, Department of Physics, Imperial College, London
 D.Sc. (Honoris Causa), University of Gulbarga, India
 D.Sc. (Honoris Causa), University of Dhaka, Bangladesh
- 1994 Brazilian Order of Scientific Merit in the Grade of Great Cross
 President, International Centre for Theoretical Physics, Trieste (1994-96)
 Book: *Selected Papers of Abdus Salam (With Commentary)*, edited by A. Ali, C. Isham, T. Kibble, Riazuddin. Singapore: World Scientific Publishing Co.
 Book: *Renaissance of Sciences in Islamic Countries*, ed. by H.R. Dalafi and M.H.A. Hassan. Singapore: World Scientific Publishing Co.
- 1995 J.C. Maxwell Prize and Medal, Academy of Creative Endeavors, Moscow
 Elected Honorary President for Life, Third World Academy of Sciences, Trieste, Italy
 Elected Honorary President for Life, Third World Network of Scientific Organizations (TWNSO), Trieste, Italy
- 1996 Died at home in Oxford, England, November 21.
 Buried in Pakistan.

Foreword

Dr. Riazuddin
National Professor and Director General,
National Centre for Physics (NCP),
Quaid-i-Azam University, Islamabad



4. Riazuddin

It is a great privilege and honor for me to contribute the Foreword to this important book dedicated to the life and work of Professor Abdus Salam. Abdus Salam was one of the profoundest physicists of the 20th century. He not only left a lasting mark in physics but also in the hearts of thousands of physicists, who owed their academic survival and development to the International Centre for Theoretical Physics (ICTP) in Trieste, which is now very appropriately named after him. Very few have the opportunity to discover a universal law of nature, but still fewer have the conscience and ability to found an institute of learning and research for the underprivileged. Salam accomplished both. In the words of Freeman J. Dyson, "Salam was great as a scientist, greater as an organizer, greatest as a voice of conscience, speaking for the advancement of science among the poorer of mankind."

I met Professor Abdus Salam for the first time as my teacher of Mathematics at Punjab University in Lahore almost fifty-six years ago. He was already a legend in Pakistan. In the fiercely competitive academic climate of pre-partition India, he not only passed every examination at the Punjab University but set new records. Salam went to Cambridge in 1946, there he excelled equally and got a double first in the Mathematics and Physics Tripos examinations of the University of Cambridge. He began research at the Cavendish Laboratory in 1949. His Ph.D. thesis published in 1951, contained important work concerning the quantum field theory of the electromagnetic force. This work had an immediate impact and he was at once recognized as a major contributor to the field.

After a brief visit to the Institute of Advanced Study in Princeton, he came back to his alma mater Government College Lahore in 1951 as Professor of Mathematics and Head of the Department of Mathematics of the Punjab University. In an environment where still relatively primitive mathematical methods were taught, we were fortunate to learn from Salam modern mathematical techniques in certain branches of applied mathematics. Obviously,

in that environment where he could not interact with fellow scientists working on exciting cutting edge problems, his choice was starkly between intellectual death and migration to the West to work at an intellectually stimulating institution. He made the only choice available to an inquiring mind and left for Cambridge to take up a lectureship in mathematics at the end of 1953.

I believe that this choice left a deep impression on him. His enforced exile lay behind his determination to do something for physicists working in developing countries under difficult conditions so that they would not have to make the choice he was forced to make. This determination was behind his proposal on 22nd September 1960 as a delegate from Pakistan to the International Atomic Energy Agency. This proposal resulted in his greatest achievement – the creation of the ICTP, an institute for the underprivileged. This is what he said: "... What is needed at this stage is that an active international centre should exist. ... Only then can first rate men from less privileged countries come periodically as of right to relive with their peers – the pioneers and thinkers of the international world – and thus give of their best of creative research." ICTP under his tireless and dynamic leadership has touched the lives of so many physicists all over the world. Among his other initiatives for the progress of science and technology in the Third World countries was the founding of the Third World Academy of Sciences (TWAS) in 1983 and its affiliated organizations providing "an international forum for uniting distinguished scientists from the South for the purpose of promoting scientific capacity and excellence for sustainable development in the South."

Abdus Salam played a crucial role in laying the foundations of the present theory of particle physics – the physics of the subatomic heart of matter. The most important of his contributions was his theory of the unification of two of the fundamental forces of Nature – the weak nuclear force and the electromagnetic force. The weak nuclear force is responsible for radioactivity without which the stars would not shine and the electromagnetic force is responsible for the binding of atoms and is crucial to all known phenomena of life on earth. For this work he shared the 1979 Nobel Prize for Physics with Harvard University physicists Sheldon Glashow and Steven Weinberg. They were searching for unity in the tradition of Newton, Maxwell, and Einstein. Their unified theory was formulated in its final form in 1967.

Passive tolerance of poverty in the Third World was of deep concern to Salam. In fact as early as 1961 in his presidential address, entitled "Technology and Pakistan's Attack on Poverty", at the 13th Annual All-Pakistan Science Conference in Dhaka, he said: "Our independence in 1947 could have provided us with the necessary stimulus. Unhappily this was not the case. Our independence did not—definitely did not—coincide with the emergence of a political class which made economic growth the centre piece of state policy. I

can still recall the interminable arguments, conducted in private and public in the early years of Pakistan, about its ideology. Never in these discussions did I hear the mention of total eradication of poverty as one of the primary ideological functions of our new state." We have still not come out of such discussions. The fact is that our poverty is due to our backwardness in science and technology. By remedying this problem we create economic prosperity that promotes world peace and human progress. This is echoed in Salam's many writings included in this volume.

"Progress," Professor Abdus Salam used to say, "begins with the belief that what is necessary is possible." The National Centre for Physics (NCP) in Islamabad is a step in the fulfillment of his dream to bring about a renaissance of science in Islamic countries. He helped launch an annual 'International Nathiagali Summer College on Physics and Contemporary Needs' in 1976 hoping that it would eventually evolve into a national centre devoted to research on the pattern of ICTP. It did in the form of NCP. The lack of such an institution drives first-rate scientists to migrate to foreign lands. The NCP plans to have all the ingredients – the faculty and facilities, to bring the standard of physics in Pakistan to par with the international norms of productivity and originality and act as an entity for generating ideas and to acquire, transmit and disseminate knowledge in the realm of physics for Pakistani Universities and R&D organizations. If Salam were alive today, I am sure he would be delighted to see that some aspects of his vision are at last being transformed into reality.

It is indeed gratifying that a research scholar of the stature of Dr. Anwar Dil has undertaken the task of writing books on eminent men of letters and scientists of our time including Norman Borlaug, Raziuddin Siddiqi, M.S. Swaminathan and now Abdus Salam. This indeed is a commendable effort which deserves the highest appreciation and would go a long way to inspire our younger and future generations. The material on Abdus Salam has been immaculately selected, edited, and introduced. I am sure it will bring out that most distinguished aspect of Salam's personality, namely, that he combined scientific excellence with doing social good.

In addition to seeking unity in seemingly disparate forces of nature Salam sought unity in humankind. As Dr. Munawar Karim says: "He outgrew his accomplishments in physics and became statesman whose name is familiar from Seoul to São Paulo, who founded an institution which has benefited tens of thousands of most underprivileged students who kept open a channel to the West to physicists behind the iron curtain when no one else would have them." The Abdus Salam International Centre for Theoretical Physics is a unifying force among the diverse people in Spaceship Earth. It helps to improve mutual understanding among people from diverse traditions and cultures, religions,

political systems and races, an important ingredient for peace and socio-economic conflict resolution. Thus he was justly awarded the "Atoms for Peace Prize" in 1968 and several other Peace Awards.

Yet Salam felt that he had failed in one of his lifelong goals, perhaps the one closest to his heart. Near the end of his life he lamented: "Countries like Turkey and my own country Pakistan have no science communities geared to development, because we do not want such communities. We suffer from a lack of ambition towards acquiring science, a feeling of inferiority towards it, bordering sometimes even on hostility." But was it a failure? Professor Fayyazuddin points out the following story: "Oscar Wilde was sitting in his club drinking to forget the failure of his play. Somebody came to sympathize with him. Oscar Wilde said: My play was a complete success, the audience was a failure." Salam was a success, but his audience was a failure. However, the environment for science and technology development is now much better than it used to be. There is an enormous increase in the science and technology budget by the Government of Pakistan and efforts are being made to create scientific communities Salam would have liked to see.

On November 21, 1996 Professor Abdus Salam passed away. He takes his place in history alongside great physicists and as a crusader consumed by a desire to promote science and technology in the Third World for their own material and cultural improvement. He left the message: "Today the third world is only slowly waking up to the realization that in the final analysis, creation, mastery and utilization of modern Science and Technology is basically what distinguishes the South from the North. On Science and Technology depend the standard of living of a nation. The widening gap in economy and influence between the nations of the South and the North is essentially the Science and Technology gap. Nothing else – neither differing cultural values, nor differing perceptions of governance – can explain why the North (to the exclusion of South) can master this globe of ours and beyond." Here he has picked the most important factor in our development. Now that Salam is gone, it is for each of us, in our own humble way to carry further his ideals.

I recommend this excellent book on Professor Abdus Salam's vision of science and technology for world peace and prosperity to readers and libraries around the world.

Islamabad
July 4, 2007

Life and Work of Abdus Salam: An Introductory Essay

Anwar Dil

1. *An Inspiring Scholar: Some Personal Remembrances*

The year was 1940. Baaji, my father, entered the house with a radiant, smiling face and said, "*Anwar di Biji, Mobarak, Mobarak!*" (Anwar's Mother, Congratulations! Congratulations!) He had a bag full of pound cakes and pastries. We knew something very special had happened. Before we could ask him he said, "Abdus Salam, a Muslim boy from Jhang has stood first in the matriculation examination. He has created a new University record of highest marks obtained by anyone so far!" I was in my sixth grade so I did not grasp the full importance of the news but celebrated the occasion by eating my fill of cake and pastries – so did my younger sisters Nasim and Shamim. Biji, of course, was more interested in finding out about Abdus Salam and who he was.



5. Abdus Salam,
1940

In the next day's newspaper we saw his photograph with the turban and learned that he was the son of a Muslim family of modest means in a rather remote town in the Punjab – away from the main centers of educational and cultural activities like Lahore and Amritsar. The matriculation examination was conducted in those days by the University of the Punjab, Lahore, covering the Punjab Province, North-West Frontier Province, and a number of other adjoining areas. Abdus Salam had stood first among several thousand students appearing in the matriculation (high school final) examination that year. Salam topped the university list again two years later in F.Sc. and we learned that he had been admitted in the prestigious Government College, Lahore, for his B.A. Honors studies.

Baaji often reminded me during my school years that I should follow the path of Abdus Salam and do the best I was capable of. I must say it helped me some, because in my 8th grade examination I stood first among several hundred students in Abbottabad and was awarded a merit scholarship. More importantly, two years later in 1945, in my matriculation examination I stood first among several thousand in the North-West Frontier Province, won a merit scholarship, and was admitted to the Government College, Lahore.

1.1 Naturally, one of the first things I did after joining the college was to find out about Abdus Salam, who had been an inspiration to me and, even though I could not reach anywhere near him in his marks in the matriculation examination, I had done much better than I would have without Baaji holding him up to me as a model. I learned that he was living across the street in the New Hostel – I was in the Quadrangle Hostel – and that he was studying for his Master's degree in Mathematics. A few days later I was having lunch in the dining hall, when someone at our table said, "That's Abdus Salam!" He was on the other side of the hall, with his friends. I wanted to go and shake his hand and tell him how important an influence he was in my life, but I was at the time only a "First Year Fool" (that's what all of us in the first year of college were called!) so I had to wait for the right opportunity. I wanted to talk to him when he was alone and free to let me say my few words to him. For that day it was enough that I had seen him – a very handsome person, laughing and enjoying his lunch.

1.2 For a brilliant, senior student like Abdus Salam with his wide-ranging interests and activities there was no shortage of news coverage in the college papers, so I came to know quite a lot about him. He was the elected President of the College Union and Editor of both the English and Urdu sections of the college magazine *Ravi* – some months later he became the Editor-in-Chief. What surprised most of us, the first-year fools, was that contrary to our understanding that taking the best possible lecture notes in the classes and pouring over books for long hours was the secret of getting excellent marks, Salam was active in so many extra-curricular activities, and yet he achieved such outstanding results in examinations. What was his secret? One of my classmates jokingly explained it by quoting a folk saying that a person who has a "giddur singhi" (non-existing horn of a jackal) can achieve anything without even trying, and we said playfully that one day we should surround him and ask him where he got his giddur singhi and help us find one too. Of course, we knew of his legendary reputation of being extraordinarily gifted and very hard working!

1.3 Salam was at the time Joint Editor of the college magazine *The Ravi*, with Ms. Urmilla Sondhi, daughter of the College Principal G.D. Sondhi, as Editor-in-Chief. The first copy of the magazine I received on joining the college was the June 1945 issue with a short story entitled "The White Arm" by Salam. I must say I was quite thrilled by the opening lines: "The temple looked a weird place in the gray streaks of fading dawn. Its turrets and spires stood out boldly like legendary heroes defying hordes of unknown foes. The bleak prospect of the surrounding stretch of land, its monotony unrelieved except by the distant curve of the river bank lend to its eerie atmosphere. The temple bells, after a protracted peal, had suddenly subsided." The narrator of the story is a military officer on duty in the area who on entering the temple experiences "the gloom and light where any crime would be plausible." He sees the priest chanting unfamiliar words in front of the idol and three or four devotees performing

obeisance – one of them sobbing. The sight creates a feeling of spiritual faith in the visitor as he says: “I had read Rider Haggard’s account of temples in African deserts, of the enormous power of suggestion and mystery which the priests so well exploited. ... I instinctively lowered my head in reverence and while in that act I saw what I had missed before. Through the curtains that surrounded the idol projected an arm, all bare save for three glass bangles that clicked and danced, the arm of the Lady of the Lake. It was white, silver white, swinging a silver lamp, up and down with a graceful rhythm.” The swinging lamp blazed the finery of the idol and the observer wondered if that arm was the secret of the mystic charm. He felt a lump in his throat and the urge to kiss that hand even if he were to pay it with his life for the sacrilegious act. As he stepped forward to do so he was able to touch it lightly but more than that he was able to see her for a flicker of a second. In that act he tripped over the idol and fell unconscious at the feet of the idol. The whole temple and the village got into a wild uproar because he had defiled the temple and the Devi. Even though he was rescued by his soldiers and taken to his camp safely the village leaders made strong representations against him to his superiors. But somehow that white arm with the three bangles and the silver lamp with its light and dark shadows kept on haunting him in his dream and he felt that he had to go to the temple and see it. He wrote down his resignation from his command and camouflaged himself like a native and weaving his way behind the idol he was able to see her beautiful curves. In that moment he felt all the more deeply that: “Her arm was the symbol of that mysticism, the soul of all suggestion. The whole spell would crack and melt without it.” He returned to his camp and remained absorbed in the thought to convert to her faith and enter the temple as her worshipper for life. But he was awakened from his reverie by his men saying that the body of a woman was washed ashore that night. On hearing it he felt a strange fear that it must be her. He went to the bank of the river and learned that they had killed her because he had defiled her with his heathen touch that fateful evening. His brain started whirling and he pulled the sheet covering her to have a close look at her. The corpse was armless! Salam concluded the story with these words of the observer: “I came to the camp and tore off the resignation. I had heavy scores to reckon with the priests of the great temple.”

1.4 I went to the College library and asked the Librarian to let me borrow earlier issues of *The Ravi* to read Salam’s articles. The very first one I looked at was “Hair and Hairdressers” (1944, reprinted in this volume as Annex I). The opening paragraph was hilarious: “Hair-dressing and shaving is one of the most atrocious ordeals that have yet been the gloomy lot of civilized humanity. I have always held that Rousseau’s savage was noble – for the very plain and simple reason that he never handled a razor or a scissors.” After describing Mark Twain’s dream of a shave in the palatial barbershop of Paris, Salam narrated his own agonizing experience at the hands of the typical village barber, also known as surgeon (because of circumcision operations he performed on little boys),

match maker, and scandal monger. Salam wrote that he could recount countless stories he had heard from his barbers but preferred to refer his readers to the beauty of Alexander Pope's poem "Rape of the Lock", Shakespeare's adoration of the beard of Hercules, Sampson, whose power was in his hair, and Meredith's Shagpat, in whose head was planted one magical hair that had the power of making all men worship the person in whose head such a hair grew. I was charmed by Salam's sense of humor, but more by his knowledge of both folklore and English literature. He was obviously a delightful story teller and fun-loving person.



6. Salam, 1946

1.5 Salam was the elected President of the College Union and a brilliant speaker and debater. In one of the debates under his chairmanship in the college hall I participated on the invitation of my friend Munir Ahmad Khan (who later became Chairman of the Pakistan Atomic Energy Commission). After the program Munir introduced me to Salam. I asked him if I could see him for about ten minutes, as I had to show him something I had written for *The Ravi*. He suggested the following day so I went to his room in the New Hostel and knocked.

He half-opened the door and standing there, blocking my entrance, took my essay on my concept of a good and successful life and asked me to come and see him the same time the following week. I took the liberty of showing him my two published essays, "If I Were a Sparrow" and "Merits and Demerits of Cinema" that had won me first prizes in *The Modern Teacher* (Lahore) competitions open to all high school candidates appearing that year in the Punjab University matriculation examination. He glanced at them but did not say a word. Next week he received me a little warmly and said that he liked the concept of my essay on a good and successful life, but it needed a lot more work. My thesis that harmonizing the best in this world and the hereafter by balancing *Haquq Allah* (Duties to God) and *Haquq al-'Ibaad* (Duties to people) was good. The supporting quotations from the Qur'an and references from Al-Ghazzali's *Ihya-e Ulum al-Din*, Sa'di's *Gulistan*, Iqbal's poems, as well as from Hindu thinkers, especially Tagore and Radhakrishnan, were fine. But then looking straight in my eyes, he said the following life-transforming words that have been a challenge to me ever since: "All these quotations are just sitting there. You have to connect them and make them come alive by your own creative thinking and synthesis." He also advised me to study the writings of thinkers from some other traditions, for example, Plato's *The Republic*, Confucius's *The Great Learning*, and works of some modern scientist-philosophers like Albert Einstein's *The World As I See It*, and present an interdisciplinary, international perspective on the concept of good and successful life for all humans. He also advised me to read and bring some illustrative examples from the lives of men and women of excellence in

world history such as Leonardo da Vinci and Goethe. He asked me to see him in about three months and let him see how my essay was progressing!

1.6 I did not have another so exclusive an occasion to meet Salam but, I did see him a couple of times. One such occasion deserves mentioning here. Professor Ashfaq Ali Khan, my favorite teacher of English, was in charge of the Boating Club and asked me to join a small party of students who were going to the river Ravi for boating. As luck would have it, at the last minute, Salam arrived to enjoy the outing. During the ride to the river it was a pleasure hearing him talk about Professor Ashfaq's book *Pakistan: A Nation*¹ and the possibility of the creation of Pakistan, because by 1946 the Pakistan Movement had started gaining strong support among the Muslims throughout India. Their conversation showed that it was only a matter of time before Pakistan would be established as an independent nation-state. I remember Salam saying that after the departure of the British rulers, the new beginning would be a great opportunity for us to eradicate poverty, which was the source of most of the problems of our people: poor health, illiteracy, ignorance, prejudice, and other man-made diseases. I



7. Cambridge, 1948

was struck by the passionate, eloquent manner in which he spoke of making available modern scientific and technological knowledge and skills to upgrade the quality of life of the disadvantaged people. But the point that has stayed uppermost in my mind is the beauty and elegance that marked the multilingual conversation of both the speakers, whether they spoke in English, Urdu or Punjabi. It is one of the most radiant memories of my days at the Government College. Both of them retained this inspiring quality till the end of their beautiful lives.

Not long after that we learned that Salam had stood first in his M.A. examination and left for Cambridge University on a scholarship for higher studies. My only source of information about him during those days was Professor Ashfaq, who told me once that Salam was studying higher mathematics and theoretical physics with some of the world's ablest professors at Cambridge and as always distinguishing himself as a genius-level scholar.

At Cambridge he studied with Professors P.A.M. Dirac, Max Born, Wolfgang Pauli, and others, and earned a good name especially for his contributions to the theory of elementary particles and for advancing Yukawa's

¹ Ashfaq Ali Khan's *Pakistan: A Nation* (Lahore: Sh. Muhammad Ashraf, 1941) published under the author's pen name of "Al-Hamza".

theory of nuclear forces that predicted the existence of three varieties, carrying different amounts of electric charge. He was invited as a Visiting Fellow by the



8. Prof. Salam, 1952

Institute of Advanced Study at Princeton, where he met Albert Einstein and came to know J. Robert Oppenheimer and Freeman J. Dyson. Salam completed his Ph.D. at Cambridge under the supervision of Professor Nicholas Kemmer, the distinguished theoretical physicist.²

Even though he had offers to teach and carry on his research in England, Salam returned to Lahore in 1951 as Professor of Mathematics at his alma mater. Some months later we heard that he missed his research work at Cambridge and that it was a period of distressing professional isolation for him. I also learned from Professor Ashfaq Ali Khan that the college Principal was treating Professor Salam rather shabbily. More importantly, the sectarian riots in Lahore created problems for Salam and his community. The situation led to the declaration of the first Martial Law in Pakistan. So it came as no surprise that in January 1954 Salam left Pakistan to join as Lecturer in Mathematics at Cambridge University. But it must be said to the great credit of Salam that his great love for his alma mater was not diminished in any way and he continued giving his best to Government College, Lahore, right to the end of his life. For example, he always responded to the editors of *The Ravi* for articles both in English and Urdu and offered financial help to deserving students and others.

1.7 I must mention here that during that period I met Salam at the Annual



9. Leo Szilard

Conference of the Pakistan Association for the Advancement of Science held in 1952. I offered to assist him in any way he considered helpful. He instead asked me to go and see if I could be of any assistance to Sir A.V. Hill, Sir George Thomson, and Dr. Leo Szilard, who had all come from abroad to participate in the Conference. I mention this because I have a very special memory of Szilard and Salam. I had requested them and some other scientists from abroad to write short notes on the qualities of a good scientist and some related topics for an article I was writing on the

conference. Szilard wrote a beautiful one page statement on the qualities of a good scientist. When he gave it to me, Mrs. Szilard and Salam were both there. I read it and passed it on to Salam, who burst out laughing because Szilard had also written "a weak husband" as one of the qualities. Salam asked Mrs. Szilard if on this criterion her husband could be called a good scientist. Her reply was:

² See Kemmer's and Dyson's essays on Salam as an excellent student at Cambridge, Chapters 59 and 71 in this volume.

"No way! Just about a B average!" Salam's retort was: "My wife would have given me an A+ with the comment: No help at home!"

1.8 To Salam also I had given a similar sheet of paper with the question as to who was the teacher who influenced him most and how. He did not fill in the page for me, but when I cautiously pursued him for his response, he said that he had several teachers to whom he owed a great debt of gratitude. He mentioned Mr. Farani in high school, who challenged and guided him to achieve the distinction in his matriculation examination (see Salam's letter of thanks in Urdu on page 626 in this volume) and Professor Ish Kumar at Government College, Lahore, who inspired him to study Iqbal's works as a universalist thinker. But Salam said that if he were to choose one, it was Professor P.A.M. Dirac at Cambridge University, who towered above all others. I remember his sentence that more than anyone whom he knew Dirac's inner mind was full of such riches and subtleties that to him he was "a walking wonder".



10. With Prof. P.A.M. Dirac, 1950

1.9 The first major public recognition of Dr. Salam's scientific work I read was a lengthy article published in *The Pakistan Times* (August 27, 1957).³ Mian Iftikhar-ud-Din, the owner and publisher of the newspaper, during his visit to England had learned of the important scientific discoveries that were bringing Salam to the attention of world scientists and had led to his appointment as Professor and Chair of Applied Mathematics and Theoretical Physics at Imperial College in London. Salam's contributions to Reflexion-Symmetry Principle were ranked alongside those of Prof. Lev Davidovich Landau, Head of the USSR Academy of Sciences⁴ and the Chinese Professors Chen Ning Yang and Tsung-Dao Lee of Princeton University and Columbia University respectively. Salam had sent his paper in November 1956 to the Nobel Laureate Prof. Pauli at Zurich, who wrote back to him "to think of something better." And even though the Italian journal *Il Nuovo Cimento* was ready to publish his paper, Salam withdrew it. In January 1957, Professor Landau, working independently, published his paper on the subject in *Nuclear Physics*. Professors Yang and Lee's paper was published a month later. Interestingly, Yang and Lee had seen Salam's paper before they wrote theirs in



11. Imperial College, 1958

³ See Chapter 43 in this volume.

⁴ Dr. Landau received the 1962 Nobel Prize in Physics for his pioneering work in developing a mathematical theory of superfluidity.

January, but the blaze of American press (notably *The New York Times*, *Time*, *Life*, *Scientific American*) and media coverage focused on the names of the Chinese-American Professors Yang and Lee, who had lived and worked together at Princeton University. This led to the award of the 1957 Nobel Prize to them for their research refuting the law of conservation of parity that at the subatomic level nature does not distinguish between left and right-handed configurations. Interestingly, Yang and Lee had acknowledged in their published paper that they had received Professor Salam's paper "on a theory of the neutrino similar to the one discussed in the present paper." Professor Pauli in a letter dated January 27 had written to Professor V.F. Weisskopf of the Massachusetts Institute of Technology: "This theory is contained in essentially identical form in an earlier paper by Salam, which I received as a pre-print already six to eight weeks ago. I wonder if it is known in the USA." The fact that Salam had reached the result before Yang and Lee and Landau – even though he did not win the shared 1957 Nobel prize – put him squarely in that distinguished group of theoretical physicists. Not long after the publication of this article Salam was awarded the Honoris Causa degree of D.Sc. by the University of the Punjab, Lahore – the first of thirty-six awarded to him by universities around the world.

1.10 This volume of selected essays by Salam (Part I) and some of his teachers, colleagues, and students (Part II) on his life and work in the context of



12. With L.H. Usmani, 1960

world peace and human progress covers most of the points that deserved to be covered in this section. However, one particular dimension deserves to be noted here. The fact that Salam had to leave his home country to do his scientific work abroad made him all the more devoted to give his best to Pakistan. His best opportunity to serve his homeland came when General Muhammad Ayub Khan came into power as President of Pakistan in 1958 and met Salam at the Science Conference. Ayub Khan asked Salam to advise him on scientific matters, especially those related to developing atomic energy. In 1959, Salam was associated with the Pakistan Education Commission and also appointed as a member of the Scientific Commission. I remember the colorful ceremony in the Punjab University Hall, where President Ayub Khan in his presidential address paid Salam the compliment: "I must say, how happy I am to see Professor Salam in our midst. His attainments in the field of science at such a young age are a source of pride and inspiration for us and I am sure his association with the Commission will help to impart weight and prestige to the recommendations."

It was on Salam's recommendation to President Ayub Khan that Dr. L.H. Usmani, a former student of the Nobel Laureate Professor George P. Thomson, who had supervised his Ph.D. dissertation, was shifted from his civil service position and appointed to succeed Dr. Nazir Ahmed as the Chairman of the

Pakistan Atomic Energy Commission. When Salam officially became the Scientific Adviser to President Ayub Khan in 1961, he and Dr. Usmani were able to collaborate on important projects, including the building and testing of the first missile by Pakistani scientists. Salam used his personal contacts in placing many young Pakistani scientists for higher education and research in important scientific institutions that later helped Pakistan acquire nuclear status. He was instrumental in the creation and development of the Pakistan Institute of Science and Technology (PINSTECH) in Islamabad. In 1962, he was appointed the first chairman of the Space and Upper Atmospheric Research Committee (SUPARCO).

In July 1973, at the Conference of Islamic Countries at Lahore, Salam presented a memorandum for the creation of an Islamic Science Foundation. The Foundation was to start functioning, in Salam's words, as a "non-political, purely scientific organization, and run by eminent men of science and technology from the Muslim world," with two objectives, building up of a high-level scientific personnel and building up of scientific institutions. He proposed an endowment fund of one billion U.S. dollars to be donated by the Islamic countries. Salam's proposal gained the acceptance of the authorities, but the donations pledged were far short of what was required. In 1976, on his initiative, the International Nathiagali Summer College Series on Physics and Contemporary Needs was started. It is continuing to do good work annually with remarkable success. Professor Saeed A. Durrani of Birmingham University has described in this volume Salam's idea of the Joint Commission on Science and Technology for Sustainable Development in the South (COMSATS), which after years of his efforts, was established on October 4, 1994, with headquarters in Islamabad, though Salam was too ill to attend the inauguration ceremonies. Salam's initiative and efforts toward establishing and developing PINSTECH, International Nathiagali Summer College, and COMSATS are part of his lasting contribution to the scientific development of his home country.

1.11 An especially inspirational memory of Salam for me goes back to February 1961 in Ann Arbor, Michigan where I had gone to study Applied Linguistics. In a letter from Lahore I received some press clippings on Salam's presidential address at the XII Annual All-Pakistan Science Conference held at Dhaka, East Pakistan. I believe that was the first time his deep commitment to upgrading the quality of human life and development of the Third World came to national and international attention. (The complete address entitled "Technology and Pakistan's Attack on Poverty," is included in this volume as Chapter 2.)

Salam began his address by saying that he would have liked to speak on a subject in the scientific field of "the elementary particles of physics – those ultimate constituents of which all matter and all energy in the Universe is composed" and how "some of the concepts the physicists have created to comprehend God's design." And that he would have liked "to show that with all

his pragmatism, the modern physicist possesses at once the attributes of a mystic as well as the sensitivity of an artist ... [and] to convey some of the wonder, some of the fascination, as well as some of the heartbreaks of the physicist's craft." But he had chosen instead to follow Professor P.M.S. Blackett's Presidential Address on "Technology and World Advancement" at the 1957 Annual Conference of the British Association for Advancement of Science held in Dublin, Ireland. He was doing so, because he believed like Professor Blackett that technology embraces "the scientific organization of most modern life" and "a mere scientist may also express himself on ideological matters, not because he has new insights to reveal but because there are things he believes passionately in and that needed saying and cannot be said often enough."

Salam added that he was focusing on Pakistan, because his country shared poverty with the majority of the human race and that the uneven distribution of wealth among the rich nations and the poor nations is of a relatively recent origin. Some recent developments in science have made it possible to eliminate early death and other such problems, as has been demonstrated by some countries transformed by scientific and technological knowledge. He believed that the provision of technical skills is very important in this process of transforming the society for which the country must take science and technology seriously by "harnessing of its spiritual energy, to the objective of eradication of poverty within one generation. This will need constant reiteration of the economic objectives; in particular this will need convincing the nation that the economic policies are designed to enrich the whole society and not merely a part of it."

Salam concluded his seminal address with these memorable words: "Let us be absolutely clear about the nature of the revolution we are trying to usher in. It is a technological and scientific revolution and thus it is imperative that topmost priorities are given to the massive development of the nation's scientific and technological skills. And finally, let us, as scientists, face and live up to the challenge thrown up by Pakistan's poverty." And he closed with a quotation from the Qur'an: "The Lord changeth not what is with a people until the people change what is in themselves."

Salam's address was widely covered in the press and the media and inspired several commentaries by leading thinkers in both East and West Pakistan. I will refer only to one entitled "Basic Development and the Cost of Human Suffering" by "Al-Hamza" (Professor Ashfaq Ali Khan's pen name) published in *The Pakistan Times* (February 14, 1961)⁵ calling Salam's address "most stimulating" and saying that "Dr. Abdus Salam has made an important contribution to the understanding of the economic problem of this country" and shown how Pakistan could make "the economic transition to prosperity ... in achieving a rate of growth as rapid as the Russian and the Chinese but without the corresponding

⁵ Reprinted as "Basic Development and the Cost in Human Suffering" in *Post-Revolution Pakistani Themes*, by Al-Hamza. Lahore: The Progressive Papers Ltd., 1961, pp. 141-45.

cost in human suffering." Al-Hamza strongly supported Salam's plan of building the scientific and technological foundations of Pakistan.

1.12 Listening to Professor Salam's Iqbal Memorial Lectures in March 1965 remains as a high mark in my studies in the history and philosophy of science. He delivered five lectures on the symmetry concepts in modern Physics from Radio Pakistan, Lahore. He said that he took pride in the fact that his lectures were associated with the name of Muhammad Iqbal, "our greatest poet, our deepest thinker," who "fully recognized that there is no finality in philosophical thinking, and that the progress of all philosophical thought must depend on new discoveries in the field of science. Again and again in his lectures on *The Reconstruction of Religious Thought in Islam* (Lahore, 1930), he points towards the possibility of breakthroughs still to come in the field of physics which may give a new outlook to philosophy. ... My second reason for welcoming Iqbal's association with these lectures is this: I believe that the rise of a great poet or a great writer or a great humanist in any civilization is not an isolated incident – that it is always accompanied by an equally significant emergence of men as great in sciences and philosophy." These were not Salam's written lectures that he read out but were talks aimed at providing "an account of man's search for unity in the understanding of the physical universe and the ultimate nature of matter. During these lectures I would like to show how rewarding the faith in the eventual unity, the eventual harmony, the eventual beauty of the basic laws of Nature has proved in unraveling some of the deeper insights we have achieved. Some of these concepts are extremely deep."

The recorded talks, transcribed and edited by Dr. Fayyazuddin and M.A. Rashid, were published as *Symmetry Concepts in Modern Physics: Iqbal Memorial Lectures* (Lahore: Atomic Energy Centre, 1966) and are included in their original version as Chapter 8 in this volume. They are an excellent record of man's history of asking questions about the nature of the universe and his search for the eventual unity underlying the general principles governing it. Salam's five half-hour lectures on this centuries-old search from the Greeks to some of the breakthroughs in our time show a mastery of the seminal works of the greatest scientists that is amazing both for the depth of his insightful understanding and the simplicity and clarity of his beautiful expression.

In his last lecture he brought his survey of all known forces of Nature to his own work in the hope of merging the internal and external properties of the elementary particles and elementary phenomena into the ultimate unified synthesis of one single whole. He concluded by saying that Physics can never rest till this final synthesis comes and that the journey for this discovery is so joyful because of our Spirit of Wonder – the deeper one goes, the more is one's sense of wonder increased!

1.13 Salam's first major contact with international scientists was in 1955 as a participant in the 5th Rochester Conference in Rochester, New York, where he

made a mark by his dynamic participation and voluntary service. The same year he was invited to serve as the scientific secretary of the First Atoms for Peace Conference convened by the United Nations at Geneva. He made excellent contacts during the time that partly led to his appointment as Professor and Head of the Department of Theoretical Physics at Imperial College in London as well as his election as the youngest Fellow of the prestigious Royal Society. In September 1960, he was invited by the International Atomic Energy Agency (IAEA) as an official delegate from Pakistan. He not only distinguished himself as a brilliant theoretical physicist but also endeared himself as the most devoted and tireless champion of theoretical physics across national and ideological borders, especially in the developing countries.

Salam's visionary proposal for the creation of the International Centre for Theoretical Physics (ICTP) attracted the attention of a number of senior scientists. Dr. Sigvard Eklund, Director General of IAEA, was especially impressed and encouraged him to develop his idea of ICTP and involve some key international scientists in support of the proposal. Salam's dynamic participation in the IAEA International Seminar on Theoretical Physics held at the Palazzino Miramare, Trieste, Italy, July 16 - August 25, 1962, led Dr. Eklund to request him to compile and edit a volume of selected lectures presented at the ten-day seminar. By this time a number of front-ranking scientists had become strong supporters of Salam's initiative for the creation of the proposed International Centre.

International Institute for Theoretical Physics
in 1962 August of this year, I drafted a proposal
before the South American Conference on High
Energy Physics, Rio de Janeiro, then came to the Atomic
Energy Commission of U.S.A. to participate in the development
of "accelerators for high energy physics and field a list of
the first Under European Conference, the CERN Laboratory
at Geneva and the first Institute for Nuclear Research, Moscow.
He then went on to express the hope that it may not be
too late when a first European Conference may meet
within a few years. I was very happy to see
such an emphasis on nuclear physics, which is the heart of
theoretical physics. I had been very much interested in the idea that
accelerators, as well as a first theoretical physics but later may
be started as an institution after the meeting started.
It includes not only Prof. Salam & his colleagues
I wish to remind the Conference that the
Atomic Energy and Theoretical Physics I shall not
hesitate in the words of Professor Eklund, who, when
first came from the Committee and later, I shall meet
with him that the first nuclear pile, which is the
construction, was made by hand. By Prof. Fermi, Prof.
Wigner. Among the first theoretical physics, I shall
with the Conference Agency are Prof. Abdus Salam,
Prof. Abdus Salam, Prof. Abdus Salam, Prof.
The Agency is now doing a lot of work in the field of
basic physics, from which I shall be able to
and I wish, the first theoretical physics, which is
the heart of nuclear physics, and I shall be able to
Agency, which is now doing a lot of work in the field of
basic physics, from which I shall be able to
and I wish, the first theoretical physics, which is
the heart of nuclear physics, and I shall be able to

13. Salam's hand-written note on
ICTP proposal, Miramare, Italy, 1960



14. With S. Eklund,
1962



15. With Eklund and
Budnich, 1964



16. With Oppenheimer
at ICTP Council
meeting, 1965



17. With G. Andreotti,
President of Italy, ICTP,
1989

The idea of ICTP had lived with Salam from 1954 when he was forced to leave his home country to save himself from his intellectual isolation as a theoretical physicist. It was in September 1960 at the Rochester Conference when the Chairman of the US Atomic Energy Commission had mentioned the desirability of creating international centers in physics that Salam talked to Hans Bethe, Robert Sachs, and Nicholas Kemmer about the practical possibility of creating such a center for theoretical physics. Luckily, the same month the annual IAEA conference in Vienna provided him the right opportunity to present a formal resolution on behalf of the delegation of Pakistan, supported by nine other international delegations. The idea received wholehearted support by some world famous scientists, notably Niels Bohr and Robert Oppenheimer. Salam's tireless work at the scientific panels convened by Dr. Eklund in 1961, 1962, and 1963 annual meetings of IAEA led to the strong recommendation for the creation of ICTP. With the dynamic efforts of Paolo Budinich, Professor of Physics at the University of Trieste, Italy, and the generous donations by the City of Trieste and the Government of Italy, the idea of ICTP was finally accepted in June 1963, and the Centre started functioning in Trieste on October 1, 1964.

Professor Oppenheimer, in spite of his terminal illness, served on the first Scientific Council of the Centre and helped draft the ICTP Charter. The following year, Oppenheimer said the following about the work and progress of the Centre: "It seems to me that the Centre has been successful in these eight or nine months of operation in three important ways. It has cultivated and produced admirable theoretical physics, making it one of the great foci for the development of fundamental understanding of the nature of matter. The Centre has obviously encouraged, stimulated and helped talented visitors from developing countries who, after rather long periods of silence, have begun to write and publish during their visit to the Centre in Trieste. This is true of physicists whom I know from Latin America, from the Middle East, from Eastern Europe and from Asia. It is doubtless true of others. The Centre has become a focus for the most fruitful and serious collaboration between experts from the United States and those from the Soviet Union on the fundamental problems of the instability of plasmas, and of means for controlling it. Without the Centre in Trieste, it seems to be doubtful that this collaboration would have been initiated or continued. In all the work at the Centre of which I know, very high standards prevail. In less than a year it has become one of the leading institutions in an important, difficult and fundamental field."

Under Salam's directorship the ICTP, co-sponsored by the International Atomic Energy Agency (IAEA) of the United Nations and UNESCO, not only became the leading world center of research in theoretical physics, especially for

Third World scientists, but also came to be recognized as Salam's greatest legacy to world science for peace and progress.⁶

1.14 The 1979 Nobel Prize for Physics was awarded to Dr. Abdus Salam of Imperial College and ICTP, and Dr. Steven Weinberg and Dr. Sheldon L. Glashow of Harvard University, "for their contribution to the theory of the unified weak and electromagnetic interaction between elementary particles, including inter alia the prediction of the weak neutral current." Their work since the 1960s was recognized as a major contribution toward Einstein's goal of a unified field theory and a new understanding of the universe. Salam and Weinberg had published jointly on their hypothesis and Glashow had independently of the Salam-Weinberg model provided important additions. The international press and media especially highlighted the intrascientific importance of Salam's continuing work on the Weak Interaction Theory, the Unified Field Theory and other related areas since early 1950s. According to some researchers in the field, Professor Salam might have been a recipient of the Nobel Prize in earlier years for his unification of the fundamental forces of nature.

Salam was in London when he received the news of the award. He got into his car and drove to the mosque to offer prayers of thankfulness. Even more than the honor associated with the Nobel Prize, he was reported by an interviewer to have said that he was proud of the fact that it was his teacher Dr. P.A.M. Dirac, for whom he had the greatest respect next only to Albert Einstein, who had nominated him for the award.



At Nobel Prize Ceremony

It was quite a treat to see Professor Salam dressed in the traditional Pakistani dress worn by Punjabi Muslims: qameez, white shalwar, black achkan (long coat), turban, and khusa (gold-braided shoes) at the Nobel Prize ceremony on December 10, in Stockholm. He looked uniquely elegant, and the photographers made capital of the handsome laureate – the first scientist so honored from the Islamic world. For Salam the occasion became especially memorable because of these words of Professor Bengt Nagel of The Royal Academy of Sciences in his speech honoring the Physics laureates: "The importance of the new theory is first of all intrascientific. The theory has set a pattern for the description also of the strong nuclear force and for efforts to integrate further the interactions between elementary particles. ... [For] our functioning as biological beings we rely on elements formed milliards of years ago in supernova explosions, with the new

⁶ Salam and some of his colleagues have reviewed the creation and work of ICTP in several of the essays included in this volume.

kind of weak force predicted by the theory contributing in an important way, really a fascinating connection between biology, astrophysics and elementary particle physics." This is precisely what Salam was working on and publishing at the time.

But even more than this the opening speech of Professor Sune Bergström, President of the Nobel Foundation, showed how well he knew and admired Salam's inspirational essays and addresses and visionary work at ICTP, especially his life's mission of extending international scientific research in the service of human welfare: "... [E]ven though our present knowledge is by no means being fully utilized, probably everyone realizes that vigorous research-and-development efforts are needed in most fields to give progress the necessary speed and at the same time to ensure avoidance of the same errors that we have had to endure in this century. It is thus only through the most advanced research and development work on the harnessing of solar energy that the tropical developing countries' energy requirements can be solved without disastrous environmental pollution under the increasing pressures of growing populations in the next half century. The most advanced biomedical and chemical research efforts are needed to quickly produce better preventive and curative methods of controlling the serious tropical diseases that are now the scourge of hundreds of millions of people. Large portions of this and other necessary research and development can doubtless be carried out best and most rapidly in the industrial nations. But it is of central importance that the developing countries' own scientific and technological competence be built up at the same time so as to ensure continued and constant local development."

In his acceptance remarks on behalf of the recipients of the shared Prize, Professor Salam said: "The creation of physics is the shared heritage of all mankind, East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says, 'Thou seest not, in the creation of the All-Merciful, any imperfection. Return thy gaze, seest thou any fissure. Then return thy gaze, again and again, thy gaze. Thy gaze comes back to thee dazzled, and made dim.' (*Al-Qur'an*, 67:3-4) This in fact is the faith of all physicists; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze. I am saying this, not only to remind those here tonight of this, but also for those in the 'Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resources. Alfred Nobel stipulated that no distinction of race or color will determine who receives of his generosity. On this occasion, let me say this to those whom God has given His bounty. Let us strive to provide equal opportunities to all so that they can engage in the creation of physics and science for the benefit of all mankind."

One week later, on December 18, Professor Salam was awarded the Honorary Doctor of Science degree by the University of Islamabad. In the following simply-worded couple of paragraphs he explains better than anything

else written on the subject of his scientific explorations recognized by the Nobel Foundation:

The theory for which I have been honored concerns the fundamental forces of Nature. Until two decades ago, physicists believed that there are four fundamental forces of Nature: the gravitational, the electromagnetic and the two nuclear forces, the weak and the strong. Two decades ago, my colleagues and I suggested that there were indications that the weak nuclear force was not really different from the electromagnetic and that the two could interconvert, one into the other. We were searching for a unity, in the tradition of Newton, Maxwell and Einstein, and the unified theory was formulated in its final form in 1967, at Imperial College, London, and the International Centre for Theoretical Physics at Trieste with which I have the privilege of being associated, and also independently at Harvard.

The first indication of the theory's correctness came in 1973, when the great European Nuclear Research Laboratory at Geneva (CERN) found experimental evidence of neutral currents, which are an essential part of the predictions of the theory. The clinching evidence was provided last year by the Stanford Linear Accelerator in the United States, which, in an epic experiment, confirmed its second aspect – its heart as it were – of the unification of the electromagnetic force with the weak nuclear to one part in four thousand as predicted. An experiment at Novosibirsk by a group led by Professor Barkov further confirmed this. ...

The next task is to test if the third force (the strong nuclear) is also part of this unity. Together with some colleagues, we have formulated this and suggested experiments to test the idea. If the results are positive, in about five years, with Allah's grace, we shall have reduced the four forces to just two.

Then will remain the final goal of uniting gravity with this electronuclear force. It is our faith that this must also be true, but a precise formulation and its confirmation may take fifty years to achieve.⁷

It is not commonly known that Salam made capital use of the prestige and renown that the award brought to him in building up the ICTP and expanding and establishing its programs on more solid foundations. In the words of Professor Freeman Dyson: "The Centre remains a monument to his energy, his vision, and his unselfish dedication to the task of bringing all peoples together in a common pursuit of science" – and, in my view, also human togetherness and cooperation for world peace and progress. Furthermore, the Nobel Prize made it possible for him to set up a special account for giving generous personal donations for creating new and strengthening existing scientific institutions in the Third World and helping talented young scientists around the world.

1.15 We all knew that Salam's second big dream was to establish The Third World Academy of Sciences (TWAS) to fulfill his dream of promoting science and technology in the Third World by helping scientists from the

⁷ See "Islamabad Lecture" (Chapter 20 in this volume).

underdeveloped countries. It took him twenty years to do so after the establishment of ICTP, mainly because he was giving his best attention to first establish ICTP on solid foundations. The prestige associated with the Nobel Prize made it easier for him to take necessary steps for establishing the Academy.

He first presented the idea of TWAS in a formal statement at the general meeting of the Pontifical Academy of Sciences in Rome in October 1981. A memorandum was drawn up on the occasion, and Salam was authorized to follow it up. He toured the world to meet and seek the support of the heads of Third World countries and world class scientists in the developing countries. TWAS was founded in Trieste in November 1983. The forty founding scientists requested Salam to be the Founding President in spite of his already heavy schedule of duties. However, finding financial support for TWAS proved even harder than it had been for ICTP. Luckily, during his visit to the Academy in 1984, to the surprise of all, including Salam, Foreign Minister Giulio Andreotti, who later became President of Italy, announced a grant of US\$1.5 million on behalf of the Government of Italy, and TWAS was officially launched at an international conference in July by the Secretary General of United Nations. Professor M.H.A. Hassan has been serving all these years as the Executive Secretary – in recent years as Secretary General of TWAS. The Academy and its components have been very productive in their programs for upgrading the development of Science and Technology in the Third World.

Salam's tour of Third World countries also led to the decision for the creation of the Network of Ministers of Science and Technology and Science Academies at the Second General Conference of TWAS in Beijing in 1987. The Third World Network of Scientific Organizations (TWNISO) was formally founded in Trieste in October 1988 by a group of about a hundred participants who elected Salam as the Founding President. The ICTP, TWAS, and TWNISO and some other dream children of Abdus Salam, notably the Third World Organization for Women in Science (TWOWS), with their headquarters on the beautiful ICTP campus in Trieste, are carrying forward Salam's vision of science in the service of enhancing the human ideal of good life.

1.16 Early in 1988, a Pakistani scientist friend of mine sent me the gift of *A Man of Excellence: Abdus Salam, 1979 Nobel Laureate in Physics* (Ljubljana, Yugoslavia, 1987), which had two articles entitled "Abdus Salam" by John Ziman⁸ and R.M. Kidder of *The Christian Science Monitor*⁹ and three major articles by Salam. In his talk "Physics and Excellences of Life it Brings" delivered at the Fermi National Accelerator Laboratory in May 1985, Salam spoke of Robert Oppenheimer's three types of excellences: the excellence of new ideas; for the experimenter, the excellence of new discoveries and searching for

⁸ Chapter 47 in this volume.

⁹ Chapter 52 in this volume.

carrying an experimental technique to its limits and beyond; and "the very human desire to spite the theorist". To this Salam added his comment: "Oppenheimer had these excellences in mind – but also much more; he emphasized the opportunity physics afforded him to come to know internationally a class of great human beings whom one respected not only for their intellectual eminence but also for their personal human qualities – a true reflection of their greatness in physics. And, in addition, he had in mind the opportunities which physics uniquely affords for involvement with mankind – in the parlance of today, in engaging in problems of development and of enhancing the human ideal." This talk offwea an insight into the creative mind of Salam, especially because it was one of the rare personal statements on his own pleasures that physics had brought into his own life. Besides his account of the ideals of development associated with ICTP and TWAS, Salam talked about some of the "excellent and humanly great physicists" he had come to know personally and interact with. The last part of his talk described his development as a theoretical physicist especially at Cambridge with Dirac and Kemmer and later in 1951 at the Institute for Advanced Study at Princeton, where he met Einstein and had opportunities to interact with Oppenheimer and Dyson.

It was good to read the high tribute of his former colleague at Cambridge, Professor M.A. Jawson, who recognized Salam's scientific achievements on the occasion of the award of the Honoris Causa degree of Doctor of Science by the City University, London, on December 1, 1986: "Ever since his Cambridge days, Abdus Salam has had the passionate conviction that advanced scientific education should be promoted throughout the Third World. By virtue of his scientific prestige, his transparent sincerity of purpose, and the sheer justice of his cause, he persuaded international agencies that the Institute [ICTP] should be established. Facilities at Trieste were freely provided by the Italian government, a gesture worthy of Italian civilization. He was the natural choice of director, a position which he holds in parallel with the chair of theoretical physics at the Imperial College of Science and Technology, London. Since 1964, several hundred promising young scientists, from diverse nations, have spent periods at Trieste in contact with leading scientific minds, intellectually enriching both themselves and their countries from the experience. The incalculable benefits of Trieste will only become fully apparent during the next century."

Rushworth Kidder's 1986 interview with Salam, first published in the prestigious American newspaper *The Christian Science Monitor*, was representative of the growing attention his ideas for improving the human condition through Science and Technology were receiving in the international media. I will mention here only two points in the interview about which Salam always spoke with great passion: 1) the issue of world peace and "defense spending" in the developed world, and 2) the growing "great divide" between the rich nations and the poor nations. The following brief quotations in the interview are especially noteworthy in this context.

Unless you are conscious that the developed nations are squandering the wealth of this world – not only the wealth of this world but also the time and the energies of its scientists and its technologists, which could be used toward bettering humanity – you'll never get to grip with the basic challenge facing the 21st century.

And if the 'great divide' between the rich and the poor nations is not closed? Salam says that it will be increasingly "hard to ignore the [developing countries'] problems in the 21st century for two reasons. First, he says, the North will no longer be able to 'insulate itself' politically from the South. If the gap is not narrowed, he says, "What will happen is what is happening already in the Third World" – turmoil, military governments, unrest, and "people on top of each other". Second, he notes that the world-wide environment "may be affected by lack of attention to the global problems and to scientific globalism." "In that sense," he says, "no parts of the world are going to be safe from the feeling of turmoil. ..."

1.17 My next remembrance is receiving a copy of Salam's landmark 322-page special report entitled *Notes on Science, and Technology and Science Education in the Development of the South*, prepared for the South Commission, the Club of Rome and the U.K. Pugwash Group. It was published in September 1990 and internationally recognized as Salam's outstanding contribution to the work of the South Commission, under the chairmanship of Julius Nyerere, Former President of Tanzania. The Commission, an independent, non-governmental organization of Third World nation-states, had been created in 1987 to analyze



19. With J. Nyerere

the problems of the South and to suggest recommendations for their solution. In the words of Ambassador Augustin Papic of Yugoslavia, the Economist member of the Commission: "[Salam's *Notes*] was distributed not only to the members of the South Commission but to a very broad audience outside its membership, to scientists, and for many international conferences. It was everywhere well received (having several revised and improved editions). With the continued efforts of Professor Salam, or Abdus as he was called, with the intensive exchange of views and better understanding with Commissioners, his ideas were adopted and incorporated in the Report of the Commission as the role and contribution of Science and Technology in the development process, within mutual interconnection." Later it was published in a well-edited book format as *Science and Technology: Challenge for the South* (Trieste, Italy: The Third World Academy of Sciences and The Third World Newtwork of Scientific Organizations, November 1992).

The following Abstract of the Report sums it up with typical Salam precision: "This globe of ours is inhabited by two distinct aspects of humans. According to the UNDP count of 1987, one quarter of mankind, some 1.2 billion people are developed. They inhabit 2/5ths of land area of the earth and control

80% of the world's natural resources, while 3.8 billion [1990 figures] developing humans – 'Les Misérables' – the 'mustazeffin' (the depressed ones) – live on the remaining 3/5ths of the globe. What distinguishes one species of humans from the other is the ambition, the power, the élan which basically stems from their differing mastery and utilisation of present day Science and Technology. It is a *political* decision on the part of those (principally from the South) who decide on the destiny of developing humanity if they will take steps to let Les Misérables *create, master and utilise modern Science and Technology*. These notes are devoted to this topic." (Italics in the original)

In spite of his failing health because of a neurological ailment, he traveled around the world meeting and eliciting the support of key figures and devoting a great deal of his time in making substantive contributions to the Commission's deliberations. Chairman Julius Nyerere acknowledged the fact that even though Salam was the only scientist member of the Commission, he was able to convince the Commission members that the development of the South depended on giving the highest priority to science and technology. This resulted in the special emphasis given to this dimension in the Commission's published report. Salam knew the importance of the South Commission and in his position as Founder-Director of ICTP, Founder President of TWAS, and Founder of the Third World Organization for Women in Science (TWOWS), he convened the inaugural meeting of his projected Third World Network of Scientific Organisations (TWNISO), which was attended by fifteen Ministers of Science and Technology, twelve Presidents of Academies, and seventeen Chairpersons of national research Councils, representing thirty-six Third World countries. All of the participants received copies of the *Notes* and other documents on the work of the South Commission, and under Salam's Presidency, they unanimously adopted the following text as "The Trieste Declaration on Science and Technology as an Instrument of Development in the South": "Recognising the fundamental importance of Science in socio-economic and cultural development and technological progress, and keeping in view the recommendations of the South Commission pertaining to the crucial role of Science in the Third World, as mankind approaches the 21st century, the members of the Third World Network of Scientific Organisations present at the meeting held in Trieste from 4-6 October 1988, resolve to work towards giving Science and Technology a position of highest priority in their own countries and to strengthen their collaboration with other countries of the South as well as the North."

Salam attended the 1992 meeting of the Commission in spite of his very weak health and put together his landmark book *Science and Technology: Challenges for the South* (November 1992). It was translated and published in a number of languages. The opening paragraph of his Introduction to the English edition reads as follows: "Progress in science and technology has become the determining factor of the present and, in particular, the future of mankind. This is

generally recognised but, as yet, has only been expressed in words; the practical effects of S&T, according to J.D. Bernal, have yet to be fully appreciated and put into use. In the case of the majority of countries of the South, the situation is even worse since there is too little interest in S&T, which are paid only lip service. Such an attitude, unfortunately, dominates in the South in spite of the fact that science and technology is, undoubtedly a major factor for its liberation from backwardness, poverty and exploitation." Salam was pleased that the Commission's Report "reflected the major points of the *Notes*, within the framework of overall development based on self-reliance of the South, individually and collectively." That was the first time that S&T had been dealt with in a report of such a type. Salam acknowledged that his book had greatly benefited from the international conference on "The Essential Role of Science in Technological Progress and Economic Development," which he and Louis Emmeri, Director of the OECD Development Centre, Paris, had convened at the Adriatico Guesthouse of the ICTP, Trieste, in April 1992. Salam's historic contribution to the South Commission's work was recognized by Julius Nyerere in these words: "The emphasis given to Science and Technology in the South Commission's Report – *The Challenge to the South* – is entirely due to Abdus Salam ... Despite his failing health from the end of 1988, Abdus Salam was assiduous in attending South Commission Meetings, including that called in 1992 – two years after the Report was published. That same year, encouraged by his success on the South Commission, but wanting still more emphasis, he expanded on the facts, figures, and arguments in a publication entitled *Science and Technology: Challenge for the South*. And later still, it was as a result of his initiative that the *Profiles of Institutions for Scientific Exchange and Training in the South* was prepared by the Third World Network of Scientific Organizations, and published jointly with the South Centre."

1.18 In the summer of 1996 our common friend Munir Ahmad Khan called me to say that he had gone to see Salam in Oxford. His disease was in an advanced stage and there was no cure for it. His mind was as brilliant and active as ever but his body was losing its functions. I was in Islamabad, when on the morning of November 21, I received a call from Munir saying that Salam had passed on and his body was arriving to be buried in Pakistan. The Pakistani newspapers and media gave extensive coverage to the end of a brilliant scientific career and acknowledged how Salam had tried to help Pakistan in the field of science and education. *The Dawn* of Karachi announced the "Death of a Genius" with the following opening words: "Dr. Abdus Salam, Pakistan's internationally renowned scientist and scholar, died early on Thursday morning at his house in Oxford, England after a prolonged illness. ... Dr. Salam is survived by a Pakistani wife by whom he had three daughters and a son, and an English wife by whom he had one son and one daughter. ... Dr. Salam was awarded honorary Doctor of Science degrees by thirty-six universities in twenty-three different countries." Among the numerous articles honoring Salam's life and work in

Pakistani media one of the most notable was "A Hero is Gone" by Professor Pervez Hoodbhoy of the Quaid-i-Azam University, Islamabad (*The Dawn*, November 22) saying: "With the death of Prof. Abdus Salam, the world has lost one of the mightiest intellectuals born on the subcontinent, and the most powerful and influential advocate of science for developing countries." The obituary in *The Times*, London (November 26) was a well-deserved rich tribute including the following lines: "In addition to his brilliant intellectual gifts, Salam was a man of remarkable vision and outstanding energy who played a major role in developing science throughout the world. Of particular significance was his success in 1964 in persuading the Italian government and the UN to found a research institute for theoretical physics in Trieste, Italy, the prime mission of which was to provide a base for young scientists from the developing countries to carry out research with each other and with visitors from the West. ... On a personal level, Salam was a striking man. Any young scientist who had the privilege of working closely with him invariably found it to be an exhilarating and character-forming experience. In addition to his great intellectual gifts, Salam had a genuine sense of humour, including that rarest of qualities of being able to laugh at himself. A warm twinkle would often accompany his more unorthodox suggestions as to how exactly the foundation of physics should be revolutionized."

Soon there was a large pile of tributes from around the world. A couple of the most memorable are: 1) Professor Sheldon L. Glashow, co-recipient with Salam of the 1979 Nobel Physics Prize: "Abdus Salam's life was gentle, and the elements so mixed in him that Nature might stand up and say to the world: This was a man!" 2) Professor Freeman Dyson, front-ranking scientist and humanist thinker: "Abdus Salam was one of the great spirits of our time, great as a scientist, greater as an organizer, greatest as the voice of conscience speaking for the advancement of science among the poorer two-thirds of mankind." 3) Dr. Federico Mayor, Director General of UNESCO: "Professor Salam will forever be remembered as a man of exceptional achievement and human qualities. ... He was an outstanding science leader. ... UNESCO and I have lost a friend and we shall greatly miss his wisdom, guidance and encouragement." 4) Prof. Zhou Guangzhan, President, Chinese Academy of Sciences: "His enduring efforts in promoting the progress of science in the Third World countries as well as his friendship towards the Chinese people and Chinese scientists will be remembered forever." 5) Dr. M.S. Swaminathan of India, World Food Laureate and former President of the Pugwash Conferences on Science and World Affairs: "He was one of those unique theoretical scientists who brought their enormous vision and wisdom to bear on the day to day problems of Third World science."

2. *Some Personal Glimpses of Abdus Salam*

In this section I have limited myself to three dimensions of Salam's life: a) Early career, b) Love of his family, and 3) Love of his homeland.

2.1 *Some memories of early life.* Abdus Salam was born on January 29, 1926 in a village named Santokh Das in District Montgomery (some years back renamed Sahiwal) in the home of his maternal grandfather.¹⁰ His ancestors hailed from a Hindu Rajput family. One of his ancestors was named Buddhan.¹¹ Salam's paternal grandfather, Mian Gul Muhammad, was a practitioner of traditional medicine and was known as Hakim Sahib. Salam's maternal grandfather, Hafiz Nabi Bakhsh was born and raised in Gurdaspur in the Punjab. Two of his sons were employed in the education department. One went to Ghana as a teacher of Arabic and the second rose to the position of Deputy Inspector of Schools in the Punjab. The family, in spite of modest means, was generally known and respected for its love of learning and piety.

Salam's father, Chaudhry Muhammad Husain, was the second son of his father. His elder brother, Chaudhry Ghulam Husain, born and brought up in Jhang, made a name for himself as a student of the local Government High School by scoring second highest marks among several thousand students in his high school examination conducted by the University of the Punjab, Lahore. After earning his bachelor's degree from the Mission College at Lahore, he joined the education department and rose to the position of District Inspector of Schools. After the partition of India in 1947, he migrated to Pakistan and settled in Jhang where he died in 1950. Salam was married to his daughter Umat-ul-Hafeez in 1949.

When he was about three years old, Salam was awarded a prize as "the healthiest child" in the community. But he was slow in blooming as a speaker. His father sought the help of a wise religious person in the community who looked at Salam and said good humouredly: "Oey Gonglu, bolda kiyuñ nahiñ! (O Little Turnip, why don't you speak!)" He assured his parents not to worry, however, because when he grows up and speaks the whole world will listen to him! He was exceptionally good in reading, writing and understanding, so his father arranged to educate him at home. He learned to read and write so well that when he joined the elementary school at the age of eight he was placed in grade four. By the time he was in secondary school, he had started speaking beautifully and his Punjabi, Urdu, and English conversations were unbelievably elegant and mature. He later moved to the Jhang College, which was an intermediate college

¹⁰ In most of the publications on him Jhang has been mentioned as the place of his birth. His father Chaudhry Muhammad Husain was employed in the education department at Jhang, his ancestral home town, so he was raised and educated in Jhang. For all practical purposes Jhang came to be known as the place associated with Salam's early life. In fact Salam himself stated in some autobiographical notes that he was born in Jhang.

¹¹ The Hindu name probably derived from Buddha meaning "the enlightened one" but in common parlance it means "one with long life". In 1946 I heard Salam say jokingly to a group of his friends that his critics must have called him "Buddhu" meaning "a simpleton" and that there are times when he himself feels like a Buddhu.

(classes IX to XII). In his ninth class he distinguished himself as a good writer and debater. In one of his notebooks there is a brilliant Urdu essay "Iqbal Meri Nazar mē" (Iqbal in My View) on the poet-philosopher Muhammad Iqbal. It is written in beautiful, ornate literary style of classical masters of Urdu literature and shows 13-year old Salam's unbelievably extraordinary ability in his understanding of the greatness of Iqbal (reproduced from the original notebook on page 626 in this volume).

In 1940, Salam appeared in his matriculation examination. On the day of the announcement of the result by the Punjab University, Lahore, he was with his father in his office. They were all overjoyed to see the front page story in the Lahore newspaper that Abdus Salam, a 14-year student of the Government Intermediate College, Jhang, Roll Number 14888, had earned 765 out of 800 marks. He had stood first in the Punjab University and created a new record of the highest marks obtained by any student in the history of the University. After hearing the result Salam got on his bicycle and started for his home, which was about two miles away. By that time the good news had spread all over the city, and he found that the shopkeepers and neighbors were rejoicing and waving to congratulate him. As chance would have it, he had gone for a haircut a few days back, and the barber had cut his hair so short that it almost looked like a shaved head, so Salam, in his words, was "wearing a turban to hide it". His photograph that appeared in the newspapers was with that turban on (reproduced at the beginning of this essay).

When he was a student of F.Sc. in Jhang, he served as Editor of the college magazine *Chenab* – named after the nearby river Chenab. One of his published essays was on the great Urdu poet Mirza Asadullah Khan Ghalib explaining why and when he had changed his *takhallas* (nom de plume) from *Asad* to *Ghalib*. It was considered so good that Maulana Salahuddin Ahmad, Editor of the leading Urdu literary journal *Adabi Dunya* of Lahore, published it with a note of appreciation. Salam was always proud of this recognition of his scholarly effort when he was only fifteen years old. In Jhang one of Salam's close personal friends, with whom he liked to spend time for literary discussion, was the Urdu poet Sher Afzal Jafry. They loved to read together and discuss Punjabi, Urdu and Persian poetry. Jafry became a nationally important poet. Salam always called him his mentor and guide in Urdu and Persian literature. All his life Salam loved to read and quote from the poems of Iqbal and Ghalib and the master Persian poet Jalal-ud-Din Rumi.

In 1942, Salam left Jhang to join the Government College, Lahore for his bachelor's degree studies. He selected the following subjects: Mathematics A, Mathematics B, English Honors, and Urdu. He was equally outstanding in all his subjects. In 1943, he published his first mathematical paper entitled "A Problem of Ramanujan" in the *Mathematics Student* (Vol. XI, No.1-2). It is included as the opening paper in the book of his scientific papers edited by Ali et al (1994). In the words of the Editors: "[It] is a remarkable contribution from a 17-year-old

student at Government College, Lahore, in which he describes a better way of solving a set of coupled nonlinear algebraic equations than the ones found earlier by the Indian mathematical genius Srinivasa Ramanujan. It shows that from a very early age Abdus Salam exhibited astonishing mathematical ingenuity and originality. It is of course a mere foretaste of what was to come." In his B.A. examination Salam secured 451 out of 500 marks and stood first in the University.

For his Master's degree he oscillated for some time between English Literature and Mathematics. Luckily, he chose to study Mathematics, which later became his foundation for studying theoretical physics. In 1946, he earned his Master's degree by again securing the first position in the university. Soon after the result was announced he left for England on a special scholarship. The story of his good luck in getting the scholarship and admission in the University of Cambridge shows how chance played such an important role in his career at that critical juncture. Sir Khizar Hayat Khan Tiwana, Chief Minister of Punjab, had collected a large amount of money for supporting the British in World War II. When the war ended in 1945, he decided to use the money to create a "Farmers' Sons Scholarship". Six awards were decided for higher studies in England. The Chairman of the Award Committee, Dr. Mian Muhammad Afzal Husain, then Vice-Chancellor of the University of the Punjab, knew Salam and his outstanding academic achievements. Even though Salam's father was not a "farmer", he had a small piece of land as his property, which technically qualified him for the scholarship. In fact, the Vice-Chancellor called Salam and advised him to apply for admission in a British University immediately, because he had decided to award him the scholarship even without a formal interview and other routine requirements.

Salam was lucky beyond everyone's dream to be informed of his admission to the University of Cambridge on the 4th of September; his scholarship was announced on the 5th of September; and he was on his way to Bombay to be on the ship sailing for England on the 8th of September, 1946. The following year Pakistan was established and the other five scholarships were cancelled!

At the University of Cambridge, Salam was impressed by the near reverence the students had for their professors and the careful notes that they took of the professors' lectures. He was also greatly impressed by the strict discipline that all students had to live by. There was nothing to prevent him from maintaining his high standards of academic achievement and he earned a double first in Mathematics and Physics Tripos examinations. For his Ph.D. work he went to the Cavendish Laboratory in 1949 and completed his dissertation on the quantum field theory of the electromagnetic force that was recognized as a major contribution in the field.

In 1951, after some months of lectures and research as an invited Visiting Fellow at the Institute of Advanced Study at Princeton where he met a number of outstanding American scientists, including Albert Einstein and J. Robert Oppenheimer, he returned to Government College, Lahore, as Professor and

Chairman of the Department of Mathematics. He also served as Chairman of the Department of Mathematics at the University of the Punjab. He enjoyed his teaching and guiding his students but felt totally isolated from the scientific world. In a guest editorial entitled "Aiding Physicists in Developing Countries" (*Physics Today*, November 1978, p. 112), Salam wrote the following about his problem: "When I returned to Pakistan in 1951 after working at Cambridge and Princeton in particle physics, I could, in a country of ninety million, call on just one physicist who had ever worked with Dirac's equations, for discussion, advice and stimulation. The most recent issues of the *Physical Review* available were dated just before the Second World War of 1939. The dues for The American Physical Society cost nearly one month's salary every year. There were no grants whatsoever for attending symposiums or conferences. The only time I did attend a conference in the United Kingdom I paid a year's savings. To add to my agony, I felt physics was relevant to my country's needs only indirectly by enhancing me as a teacher."

Because of this stifling feeling of isolation from scientific contacts, he decided to return to Cambridge University as a lecturer in 1954 and resume his research work in theoretical physics. As luck would have it, Professor Blackett, the 1948 Nobel Laureate, who was then Chairman of the Department of Physics at Imperial College, London, was visiting Cambridge where he met the 1967 Nobel Laureate Professor Hans Bethe and asked him to recommend a suitable person to be appointed Professor of Theoretical Physics at Imperial College. Bethe, who knew Salam and his brilliant scientific work and genius-level potential, said that Abdus Salam was by far the best person for the position. After the interviews and evaluation by the leading British scientists the appointment of Salam as Professor of Theoretical Physics at the Imperial College of Science at the young age of thirty was flashed all across England. He was the second Professor from South Asia in the whole of England – Dr. S. Radhakrishnan, who later became the President of India, was the first to have been appointed Professor of Philosophy at Oxford University. Professor Salam's inaugural lecture on Elementary Particles was presided over by Professor Blackett, who said in his introductory remarks: "Dr. Salam had a meteoric academic career in Pakistan and seemed to possess an extraordinary facility for being unable to pass any examination in any subject except at the very top of the list. ... In 1955, he showed his administrative gifts by becoming one of the scientific secretaries of the great international conference at Geneva on the peaceful uses of atomic energy."

2.2 *Salam's love of his family.*¹² Chaudhry Abdur Rashid, the younger brother of Salam, remembered him as his "brother, parent, and teacher" who kept a schedule of a sixteen-hour day of study and work and lived an unbelievably

¹² This section is based mainly on published remembrances of Salam after his death in Pakistani press, mainly in Urdu language, by some members of his family.

simple life. His sister Begum Hamida Bashir called him "an ideal human being" and admired him especially for keeping his things very tidily in his room and saying that each thing should be kept in its proper place so that even in darkness one could find it easily. He was very punctual in going to bed, waking up, performing religious duties, and studying. She proudly remembered his getting a trophy awarded by their native city of Jhang for his being the most beautiful and healthy child when he was about four years old. She also recalled that he was very fond of wearing Pakistani perfume and always liked to take small bottles of perfume as gifts for his international friends.

Salam's first wife, Begum Umat-ul-Hafeez, remembered the forty-seven years of their married life since 1949, as the most precious part of her life. He was always so absorbed in his work that he seldom concerned himself with any housework and left it all to her. He went to sleep around 9 p.m. and got up around 3:30, and after a simple snack, was at work by 4 a.m. until 7 a.m. when he got ready and after breakfast left for college at 8 a.m. After spending the whole day there he would come home for dinner and after a short rest be at work again until bedtime. There were days when he had to work longer, so he would get up at 2:30 a.m. He was all the time absorbed in his work – even during his meals he had a pen or pencil nearby and would write his thoughts or equations on a napkin or whatever was around. He observed all the religious duties very punctually. He was very fond of reciting the Holy Qur'an and always carried a small pocket edition with him and read from it as often as he could, especially during his journeys. He was always very strict about the education and training of his children. Every evening when he was home, he made a point of asking each child what he or she had learned or done during the day. If he found any of them having an academic problem, he took time to help them. His constant advice to the children was never to tell a lie. He exhorted them to work as hard as possible, because one must do one's very best in whatever one is doing and then leave the result to God. He was very affectionate to all of them. He was also very careful in meeting the needs of his brothers and sister, because he was the eldest son in the family and his father's income was not enough to meet their needs. He helped them by financing their education and weddings. All members of his family knew that he was a very exceptional person, so they did all they could to enable him to devote himself fully to his work.

Salam's eldest daughter, Aziza remembered their Cambridge days when she was very small. He used to take her and her younger sister for boating on the nearby Cam. Her special remembrance, after they moved to London, was of their going out to eat fish and chips. She remembered his advice not to waste time and to stay away from frivolous activities. Her younger sister, Asifa remembered that at times he would get angry. Once she got a big scolding when he was getting ready to leave the house on a trip. She recalled, however, that on reaching the airport, he called her to say he was sorry to have lost his temper. On returning home from abroad he always brought small gifts typical of the countries he visited for all the children. Their youngest sister, Bushra remembered the dolls he

brought for her from different parts of the world. She and her brother and sisters always looked forward to the picture postcards he used to mail them from abroad. She also remembered his taking them to the museums where he would point out interesting items and explain their importance. He often gave them writing assignments and checked them in the evening.

Salam's British wife, Professor Dame Louise Johnson of Oxford University, who accompanied Salam's body for burial in Pakistan, in a published interview in Urdu translation, remembered him as a great man of our time. According to her, two of his most impressive qualities were his ability to persuade others to join in the cause of scientific work for world peace and progress, and his inspirational power to awaken latent potential for excellence in his students and colleagues. He accepted all the honors with great humility. When he fell ill and learned that his malady had no cure, he accepted it with great patience. First it looked like Parkinson's disease, but in 1993 it was found to be Palsy Progressive Supranuclear, which was a degenerative disease. Until his end he remained interested in learning about new ideas and discoveries, especially in physics and biology.

Salam's son from his Pakistani wife, Ahmad Salam wrote in his reminiscences:¹³ "My father made perhaps one of the biggest sacrifices to achieve the aims and ideals he deeply believed in: his time to be with his own children." He never heard his father talk about it much, but on one occasion when he did, the son could understand "the loneliness and sadness he went through in order to pursue his bigger goal." He narrated the story that once when his father was asked how many children he had, his reply was: "a few thousand" – the number of "his surrogate children" who had passed through the ICTP and whom he gave a lot of encouragement and inspiration in addition to help in so many ways. Ahmad Salam wrote that he always encouraged his children to read the biographies of great people in world history. From his childhood he remembered their house being full of books and magazines in every room. He was very fond of visiting bookstores. In London he liked to browse in Oppenheimer's in South Kensington and Karnac on Gloucester Road. He particularly enjoyed visiting second-hand bookstores on Richmond Hill, where he often found not only good books but also good bargains. Salam also enjoyed music, especially Urdu ghazals. He enjoyed reading Urdu poetry, especially the poems of Ghalib, Iqbal and Faiz. He also loved reading books on Islamic art, especially architecture and calligraphy. He was very fond of listening to the recordings of Al-Qur'an, especially the recitation by Abdul Basit of Egypt.

Umar, Salam's son from his British wife, who accompanied his father's body for burial in Pakistan, said that he admired his father for his most impressive quality of patience and quiet acceptance of all the pain and suffering during his long and debilitating illness – especially during his last four years. He

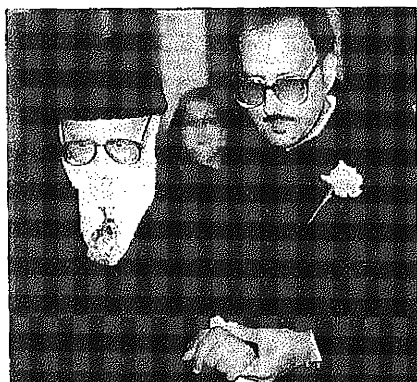
¹³ In *A Tribute to Abdus Salam*, ed. by A.M. Hamende. Trieste: ICTP, 1999, p. 124.

remembered the great joy with which his father described to him the 25th anniversary celebrations of ICTP in 1989, saying that it was the happiest day of his life and that Trieste always called him to spirituality.

Salam's grandson Imran Saadi, in his reminiscences presented at ICTP, summed up the keynote of his grandfather's personality as follows: "His humility is something that has been passed on to all of us. He told us that if something is not essential, learn to go without it and make full use of what you have. This came from his own background, which he never forgot. His own roots were very humble and he carried this throughout his own life. He also taught us that time is of the essence, and never to waste a single moment. He himself spent every minute of his life working to better all the people of the world, especially the students of the Third World."



20. Showing Nobel Prize award to his son Ahmad Salam and son-in-law, Shehab Saadi, 1979



21. At the wedding of his son, Ahmed Salam, London, 1993



22. Salam's second son, Umar Salam, 1997

2.3 Salam's love of his homeland. Salam loved Pakistan with great passion and all his life he did all he could to help his nation grow to its maximum potential. Only a couple of Pakistanis understood the nature of his scientific work but many had heard of the international honors he had earned for his researches in theoretical physics. The award of the Nobel Prize was taken by Pakistanis as a great honor to Pakistan, even though his determined efforts to establish his

International Centre for Theoretical Physics in Pakistan had failed, he had laid the foundations for such a center by helping to develop the Pakistan Institute of Scientific and Technical Research (PINSTECH) and, had created other centers of scientific research and helped numerous young Pakistani scientists to study for advanced degrees and carry on advanced level research at Imperial College, ICTP and other centers of major scientific work.

I must quote here a few lines from the very last message that Salam sent on March 13, 1996, only a few months before his death, to a conference in his honor in Karachi: "As you all know I am suffering from a rare illness which is known as PSP. This is a disease, which essentially leaves the brain functioning perfectly but slowly destroys body's physical responses. This disease has prevented me from visiting my beloved Pakistan. I miss my home country and would dearly love to see all my family and friends. I would not be with you today but please know you are in my heart and I shall be thinking of you today. ... I have tried to show to its [Pakistan's] aspiring people what a Pakistani can achieve. You as a scholar must continue to aspire and drive the future Pakistani generations to greater heights. ... It must be the role of each and every one of you to provide role model for all its citizens. We as the older generation failed to build the ideas and opportunities the country needs. We must put our differences and private agendas behind us and we must build a better Pakistan. We have wasted a great deal of time and allowed other countries to get ahead of us in the educational area. This must be halted. Never doubt your abilities to produce the best in the world. But remember the best will not come without hard work and total dedication. As Muslims we have a great heritage to inspire us and we should never forget that great and learned Muslim scholars few centuries ago led the world in so many fields. If I leave you with one final thought and a request, it is that now you must turn your minds to building a better Pakistan. The people deserve far more than we are giving them at present. Do not let them fall by the wayside simply because you are looking the wrong way. May Allah bless you and all your efforts. Once again my salam and best wishes to you all."

3. *Abdus Salam's Legacy*

In view of the fact that a number of scholars far more competent than myself have written about Salam's legacy in their essays included as Part II in this volume, I have confined myself here to some brief remarks on Salam's exemplary love of learning and his work as a scientist, and an institution builder.

3.1 *Salam's exemplary love of learning.* Salam was an exemplary life-long student determined to acquire comprehensive knowledge. He was always eager to learn new ideas wherever he found them and integrate them with what he knew and use his knowledge with selfless devotion to improve the human condition. His role models about whom he often spoke, among others, were the legendary "Scientist-Wizard" Michael the Scot (b.1175) who had left his

homeland at the age of twenty-five to devote himself to study, research and translate landmark works of knowledge at the Islamic University of Toledo in Spain, and Saif-ud-Din Salman, who in 1470 had no other choice but to leave his old father in Qandhar to carry on advanced studies in astronomy at the famous Ulugh Beg Observatory in Samargand. It was an inspiration to hear Salam speak of these and other great seekers of knowledge, especially some in our time whom he had the privilege of knowing personally, like Albert Einstein and P.A.M. Dirac.

Dr. Ram Prakash Bambah and Salam were fellow students at the Government College, Lahore in 1942. Bambah remembers the excitement when Professor Chowla, in his class in Mathematics, posed the unsolved problem of the legendary Indian mathematician Srinivasa Ramanujan, regarding four simultaneous equations in four variables. The 17-year old Salam solved it in three or four days. He had suggested that the four variables were the roots of a quadratic whose coefficients could be found by solving a cubic. At Cambridge, in 1950, Bambah recalls that Salam had renormalized longitudinal photons. When Bambah told this to Professor Freeman Dyson at Princeton, his comment was: "If he has done it he will be very famous."

Professor Dyson in his memorial article on Salam in 1999 wrote: "I met him first in England when he was twenty-four, a student ... [from Pakistan]. I was then supposed to be a leading expert on the theory of quantum electrodynamics. I quickly found out that Salam knew as much about that subject as I did. He asked me for a topic for his research. I gave him the topic of overlapping divergences, a highly technical problem that had defeated me for two years. He solved it in a few months. ... Ten years later I could see that he had grown over my head. ... The ICTP remains a monument to his energy, his vision, and his unselfish dedication to the task of bringing all peoples together in a common pursuit of science."

Dr. Ghulam Murtaza, Abdus Salam Professor of Physics at the Government College (now GC University), Lahore, in his two Urdu articles on Professor Salam calls him "ek 'ahd saaz shakhsiat aur 'azeem ustaad" (An Epoch-Making Personality and a Great Teacher).¹⁴ Murtaza, who studied under Professor Salam at the Imperial College, wrote that his style of teaching was very different from that of his colleagues. For example, Professor Paul Matthews prepared his lecture and systematically presented each point to make sure that students understood it. Professor T.W.B. Kibble practically wrote out his lecture on the blackboard, and the students copied it. Professor Salam's method was to bring some books and current issues of the journals to the class with page markers and discuss a wide

¹⁴ Published in *The Ravi*, Journal of the Government College, Lahore, Vol. LXXXIV, 1997, pp. 32-41.

range of research topics, and jotting on the blackboard different points with arrows and signs linking one with the other. Many of the students would not understand some of the points, which were often beyond the reach of their minds and yet they would be excited by the experience and carry on their discussions outside the class. Salam was always in a hurry in his lectures to reach somewhere, thereby challenging his students to rise and fly with him. That is why those who stayed on to work with him rose to such heights in their respective fields of study and research.

Dr. Salam's African student, Dr. Daniel Akyeampong of the University of Ghana, remembers Salam's "infectious excitement and enthusiasm" as an inspired scholar eager to share all that he knew with his students. It brightened his classes at Imperial College and the working lunches at ICTP: "Salam has bequeathed to us knowledge and compassion" but above all it was his "vision – which was his humanity" that is his lasting heritage.

Dr. Robert Delbourgo of the University of Tasmania knew Professor Salam as his teacher both at the undergraduate and graduate levels and as the supervisor of his Ph.D. dissertation at Imperial College, and finally as his "boss" and colleague at ICTP and collaborator on a number of research papers. He remembers the "moving experience" of listening to his lectures as a "most inspiring teacher, his breakneck speed notwithstanding". He "mixed well with the students" and was "a great source of inspiration" as a "charismatic professor." Speaking personally, Delbourgo wrote that Professor Salam shaped his character and influenced his life "at crucial stages in so many different ways".

Munir Ahmad Khan, former Chairman of the Pakistan Atomic Energy Commission, remembers his last detailed meeting in 1992 at breakfast that Salam made for him. As they ate in the kitchen he talked about his "working on applying the principles of physics and mathematics to biology for obtaining further insights into the origins of life. ... If he had lived longer he would have contributed more to our knowledge about the origin of life and how its character was determined by the weak interaction which violates parity."

Professor Gerhard Mack of the University of Hamburg remembers the last time he had a scientific discussion with him, a few months before the Salam Festival at ICTP in 1993. They were standing in front of the elevator for about ten or fifteen minutes, when Salam told him, in spite of his debilitating illness, about his developing interest in biology: "It was difficult to understand what he said. I had to get my ear close to his mouth. Nevertheless, he was full of enthusiasm. This is how I remember him."

3.2 Salam as a scientist. Salam's scientific work covers half a century of devoted research that opened a number of exciting avenues attracting the respectful attention of the foremost scientists in the world. Bound albums of his published papers are preserved in the Abdus Salam Room in the ICTP Library.

The most comprehensive published book of his scientific papers is *Selected Papers of Abdus Salam with Commentary*, edited by A. Ali, C. Isham, T. Kibble,

Riazuddin (Singapore: World Publishing, 1994). The editors write in their Introduction that Salam's two hundred and seventy-five published papers "span a huge range and contain many seminal contributions. It is quite impossible to include all the important papers in a single volume. As editors, we have had to make very difficult choices, omitting many papers that we would have wished to accommodate. We have tried to include representatives of all the different periods of his work and all the different fields to which he contributed, though inevitably some are better represented than others." The papers, arranged chronologically, are grouped under five broad sections: 1) Quantum Field Theory and Dispersion Relation; 2) Symmetries and Electroweak Unification; 3) Lepton-Hadron Unification; 4) Gravity, Supersymmetry and Strings; 5) Condensed Matter and Biology. The complete list of Salam's papers is included at the end of the book.

The book opens with Salam's first research paper, which he produced when he was a fourth year student at Government College, Lahore. In the words of the editors it is a remarkable contribution from a 17-year-old college student in which he describes "a better way of solving a set of coupled nonlinear algebraic equations than the ones found earlier by the mathematical genius Srinivasa Ramanujan. ... Salam's other early contributions, of which only a small selection is reprinted here, are far more important. He played a major role in the epoch-making advances in quantum field theory from 1950 onwards." The papers in the first section made some key advances in quantum field theory, especially concerning proofs of renormalizability, and extended the validity of dispersion relations. The selected papers in the second, third and fourth sections show his pioneering work that not only earned him the Nobel Prize, but more importantly established him as one of the leading theoretical physicists of the century for opening new avenues toward a "Grand Unified Theory". According to Ahmed Ali and his co-editors of the volume, the final section, representing his work during his last years, illustrates "both the breadth of his interests and the continuing originality of his ideas. Unlike most of his previous research, these papers are not concerned with elementary particles but with fundamental problems in condensed matter physics and biology. ... The papers presented here describe a very promising line of attack, involving field theories restricted to two spatial dimensions, corresponding to the layered structure of these materials. Also included are two papers proposing a solution to one of the long-standing puzzles of evolutionary biology – the origin of chirality or handedness in biological molecules. ... It is fitting that this selection should end, as it began, with papers demonstrating Salam's penetrating insight, originality and wide interests."

Salam's first major product of compiling, editing, and publishing of international scientific work is the monumental work, *Theoretical Physics* (Vienna: International Atomic Energy Agency, 1963). It consists of selected lectures presented at the Seminar on Theoretical Physics organized by the

International Atomic Energy Agency held at the Palazzino Miramare, Trieste, July 16 - August 25, 1962. On the inner title of the book Salam was given credit as "Director". He was at the time Professor at Imperial College of Science and Technology, London. Salam was paid highest compliments for producing the landmark compendium.

Sigvard Eklund, Director General of IAEA, wrote in his Foreword: "Theoretical physics is at present in a stage of rapid development. This makes it a very exciting field of research which attracts some of the most talented scientists all over the world. It is of vital interest to theoretical physicists to report on their latest work, to discuss the results of recent research, and to exchange ideas on the many advanced theories which are constantly being put forward. Work in theoretical physics can be done away from the gigantic research centres which are becoming ever more essential in other fields of science, but which only few countries can afford. Therefore, theoretical physics provides an opportunity for scientists in developing countries to achieve important results and to make their mark without suffering the handicaps with which experimentalists in these countries have to contend. They depend, however, on ways of communication and on a continuous flow of information which will keep them abreast of research which is performed in other countries." These lines point toward the need of an International Centre for Theoretical Physics (ICTP) formally proposed at this conference by him as an official delegate from Pakistan.

In fact, Salam's dream of ICTP came true within two years at Trieste. His Introduction to the book under his signature as "Scientific Director" had the following quotable lines:

In mid-1962, one can distinguish three major areas of ferment in theory; firstly, there is the intensive development of quantum field theory; secondly, the search for the symmetry properties of strong and weak interactions; and thirdly, the exploration of the analyticity of the scattering matrix in energy and angular momentum variables. The first four books of this volume survey these developments. ...

The concluding part of this volume (Book V) is different in spirit from the rest. Its concern is with the emerging topic of very high energies, with a survey of strong interactions from Hayakawa, of electromagnetic interactions from Ericsson and others, and of weak interactions at very high energies from Pais.

Salam's second book, *Nonpolynomial Lagrangians, Renormalisation and Gravity*, was prepared as "Session Leader and Reviewer." It was the first of five volumes in the "Tracts in Mathematics and Natural Sciences" (New York: Gordon and Breach Science Publishers, 1971), comprising lectures from the Gables Conference on Fundamental Interactions at High Energy held at the Center for Theoretical Physics of the University of Miami, Florida, January 20-22, 1971. It was hailed as "a thorough, penetrating survey of one of the most active research programs of present day particle physics." In the concluding part of his own chapter entitled "Computation of Renormalization Constants" (pp. 3-41), Salam observed:

1) The best thing which happened at this conference is the assurance that localizable non-polynomial theories are perfectly respectable field theories – in fact more or less orthodox, rather tame from an axiomatic point of view. Not only that, they are superior to polynomial theories in that they permit (with Lehmann's ansatz) an unambiguous and finite computation of renormalization constants.

2) For far too long, particle physicists have neglected Einstein's gravity. Our excuse has been the smallness of the coupling constant. We have now learnt that this neglect is one origin of the conventional infinities of quantum electrodynamics. ...

3) With F-mesons and with the postulation of the two-tensor theory of gravity, nuclear physics would appear to be another name for strong gravity ... Considering that he spent the later years of his life searching for a unification of the forces of nature, I am sure that if the Old Man were alive he would feel happy with this rather direct and amusing unification of concepts in the strongest and the weakest of the forces. As I said before, I feel we have left gravity theory too long to cosmologists. F-dominance of gravity, hadrons (and particularly quarks) as black holes mean that the experimental particle physicist has all along realized conditions of strong space-time curvature in his laboratory. His micro-universe is as good a place to study Einstein-like equations as the macro-universe. I would hope that at the next Rochester Conference, in addition to strong, weak and electromagnetic sessions, we have, as we had today, a fourth session devoted to gravity and particle physics. I hope also that by then our Chairman or some other experimental physicist will have established the quantum nature of gravitational radiation assumed throughout this lecture. (pp. 33-34)

Salam's third book, put together with E.P. Wigner as co-editor, is *Aspects of Quantum Theory* (Cambridge: Cambridge University Press, 1972), dedicated to P.A.M. Dirac "to commemorate his seventieth birthday and his contribution to quantum mechanics". In his Preface, Salam and Wigner paid the following tribute to one of the greatest scientists of the 20th century, who had presented an original formulation of quantum mechanics and a quantum theory of the emission and absorption of radiation by atoms: "Posterity will rate Dirac as one of the greatest physicists of all time. The present generation values him as one of its great teachers – teaching both through his lucid lectures as well as through his book *The Principles of Quantum Mechanics*. This exhibits clarity and a spirit similar to those of the *Principia* written by a predecessor of his in the Lucasian Chair in Cambridge." The contributors included, among others, F.J. Dyson, W. Heisenberg, A. Pais, R. Peierls, and Salam with his co-author J. Strathdee.

Salam's next important book is his 1988 Dirac Memorial Lecture, "Unification of Fundamental Forces."¹⁵ Professor John C. Taylor in his Foreword to the book writes: "From time to time, science succeeds in unifying apparently diverse sets of phenomena. These unifications provide some of the most impressive achievements in the sciences. Unification, in this sense, means

¹⁵ Abdus Salam. 1990. *Unification of Fundamental Forces*. Cambridge: Cambridge University Press.

understanding how apparently different effects are really aspects of a single underlying thing. In the nineteenth century, for example, electricity and magnetism were unified. They are different, but they are intimately interconnected, and in general situations it is impossible to imagine one without the other." (p. vii) In the 20th century one of the great achievements in physics has been the unification of electromagnetism with the weak force that are apparently totally different: "Electromagnetism ranges across any distance, from atomic to astronomical. The weak force, on the other hand, operates deep within the atomic nucleus (for example) to produce radioactive decay." (p. vii) Abdus Salam, Sheldon Glashow, and Steven Weinberg were awarded the 1979 Nobel Physics Prize for their work in the field to which a number of other scientists, notably the British physicists Peter Higgs and Tom Kibble, and the Dutch theoretician, Gerard t' Hooft have made important contributions.

Salam presented in his landmark lecture an historical perspective on the electro-weak unification within the framework of quantum theory with emphasis on the contribution of Paul Dirac. In a footnote he added that Freeman J. Dyson in his *Infinite in All Directions* (New York: Harper and Rowe, 1988) writes how, according to Dirac the very greatest scientists in each discipline are generally unifiers. "This is especially true in physics. Newton and Einstein were supreme as unifiers. The great triumphs of physics have been triumphs of unification. We almost take it for granted that the road of progress in physics will be a wider and wider unification bringing more and more phenomena within the scope of a few fundamental principles. Einstein was so confident of the correctness of this road of unification that at the end of his life he took almost no interest in the experimental discoveries which were then beginning to make the world of physics more complicated. It is difficult to find among physicists any serious voices in opposition to unification." (p. 5)

Salam then traced the variety of unifying concepts used in physics from the beginning to the "Theory of Everything" (TOE) and today's "Standard Model of Particle Physics" where, in his own words, the fun lies at the moment to determine "what the elementary entities are and to unify some of the forces of nature between these elementary entities." He begins with Al-Biruni of Afghanistan, who lived a thousand years ago: "Al-Biruni, however, to my knowledge, was the first physicist to say explicitly that physical phenomena on the Sun, Earth and the Moon obey the same laws." This was the argument that occupied the minds of all scientific thinkers in the Middle Ages. "This deceptively simple idea is the basis of all of science as we know it. This was independently stated and demonstrated by Galileo six hundred years later. Galileo used his telescope (imported from Holland) to observe the shadows cast by mountains on the moon. By correlating the direction of the shadows with the direction of the sunlight, he was able to assert that the *laws of shadow making were the same on the Moon as on the Earth*. This was the first demonstration of the fundamental principle – now known as the 'Galilean Symmetry' – which asserted the universality of physical laws." (p. 8) (*Italics in the original*)

Newton, around 1680, asserted that the force of "terrestrial" gravity – a universal force that makes apples fall to the ground, was the same as "celestial" gravity that keeps the planets in motion around the Sun: "Such a force is long-range. Its effects can be felt at any distance, though attenuated by the square of the distance between the two 'gravitating' objects concerned." (p. 9) The next unification of fundamental forces was postulated about one hundred and fifty years later by Faraday and Ampere in the context of electromagnetism, "the 'force of life' (so-called because all chemical binding is electromagnetic in origin, and so are all phenomena of nerve impulses). ... Faraday and Ampere, in the greatest unification of modern times, were the first to show that electricity and magnetism were but two aspects of one single force – *electromagnetism*. It is ... an *environmental* factor which distinguishes between electricity and magnetism – *namely whether or not the electric charge is in motion or not. This is the essence of the unification of electricity and magnetism.* ... This unification of the two disjoint fundamental forces of electricity and magnetism was the basis of electrical current technology of the nineteenth century which depended on the generation of electric currents by rotating a coil of wire between the two poles of a magnet. This is the basis of the electric motors and electric dynamos which led to the electric power stations." (p. 11)

Maxwell, fifty years later, "showed that if an electric charge is *accelerated* (i.e., its speed changes or there is a change of direction), it would emit energy in the form of electromagnetic radiation (radio waves, heat waves, light rays, X-rays, gamma rays which differ from each other in respect of their wave lengths only). This miraculous unification has been the basis of the technology of the twentieth century, with radio, television and X-rays dominating our lives." Salam added that Maxwell had unified electromagnetism with optics and "he verified that the speed of light could be expressed in terms of two known constants (which described *electric and magnetic properties of the vacuum*), as predicted by his theory."

Ten years later, Hertz of Germany demonstrated the electromagnetic radiation produced by accelerating electric charges. In 1905, Einstein's Special Theory of Relativity "placed space and time on an equal footing" and "the well-known *relationship between mass and energy*" as well as a number of other far-reaching unifying ideas. "With his General Theory of Relativity in 1915 he showed that the curvature of space and time determined gravity – curvature is a geometric notion while gravity is one of the fundamental forces of nature. Thus he was able to accomplish the geometrization of physics. Einstein started exploring the connection between gravity and electromagnetism to see if electromagnetism could be looked upon as a geometrical property of space-time to unite the two forces of nature. Einstein spent thirty-five years exploring this dream of his." Salam mentioned Kaluza's explorations in this context resulting in his 1919 paper that he sent to Einstein. Later this work was followed by Klein. Salam also referred to Friedman, a Russian astrophysicist, who considered the overall structure of the universe and found that an expanding universe could arise

as a solution of Einstein's equations. Hubble confirmed these experimentally and discovered that distant galaxies are receding from us, in accordance with these ideas. Penzias and Wilson further extended these ideas in 1965.

In the second part of his lecture Salam spoke of the two nuclear forces discovered in the 20th century: the so-called "weak" and "strong" that were "consistently ignored" by Einstein and Dirac.¹⁶ First he discussed the concept of elementarity of matter. Of the four "elementary" entities proposed by the Greeks three (earth, water and air) could be called "elementary" entities of matter while the fourth (fire) represented a force. Discussing briefly the work of Rutherford in 1910, Joliot-Curie's work in 1932, and Hofstadter's in 1956, Salam spoke of Dirac's famous equation of 1927 that was an attempt to unify quantum mechanics and special relativity. His equation described not only positive energy particles but also "negative" energy objects that had not been seen by anyone.

This led to the prediction of the existence of a new particle, the positron, as the antiparticle of the electron. Positron was discovered a few years later and advanced further in 1956 by Segre and Chamberlain and the 1965 production of antideuterons by Zichichi et al. In the words of Salam: "Dirac was a genius both in mathematics and physics" and "the equation of Dirac and its successful reinterpretation is one of the greatest triumphs of twentieth century physics." (p. 33) So, from contemporary scientific perspective there are four fundamental forces of nature: the weak and strong nuclear forces and the electromagnetic force and the universal force of gravity.

Salam devoted the third section in his lecture to the unification of the weak nuclear force with electromagnetism. The difference between the approach of Faraday and Einstein and Salam's generation of scientists is that rather than seeking the unification of electromagnetism and gravitation, today they seek the unification of electromagnetism and the weak nuclear forces, because these are the "gauge" forces. Salam started looking at the problem of unification in the 1950s. The next stage came when he moved to the electroweak unification to the strong nuclear force as a gauge force and the Standard Model and from there to beyond the Standard Model and the idea of Supersymmetry. The further stage of unification beyond the Standard Model, according to Salam, was to attempt the unification of the strong nuclear force with the "electroweak" force commonly known as the Grand Unified Theory proposed by Salam and Jogesh Pati in 1972 – and in a different version in 1974 called the new Electronuclear Force. The last stage was the quest for the unification of gravity with the other forces that was Salam's great dream.

An especially memorable occasion for Salam was the three-week Silver Jubilee of ICTP from October 14 to November 3, 1989, attended by two hundred

¹⁶ The weak nuclear force was first discovered by Madame Curie. It plays a crucial role in the energy production by the sun. It is universal but not as universal as gravity. It is called weak because of its smallness in strength compared with the electromagnetic force.

invited scientists from around the world, including six Nobel Laureates, for lectures and seminars on High Energy Physics, Mathematics and Condensed Matter Physics. The Italian Prime Minister Giulio Andreotti inaugurated the program and paid glowing tributes to Dr. Salam for creating ICTP and TWAS and, for making Trieste "The City of Science" and a world center for bringing scientists together to shape a New World. Professor Ting of CERN announced on the occasion that experimental results obtained a few weeks earlier at CERN's laboratory confirmed the theories of Professor Salam on the unification of forces in nature.

The concluding ceremonies on the 3rd of November were conducted by Prof. J. Schrieffer, the 1957 Nobel Physics Laureate, who bowed and saluted Prof. Salam and announced that the only gift they all wanted to present to him was a poem written by the famous theoretical physicist Frederick Reines (who later won the 1995 Nobel Prize in Physics):

From out of the east there came a man
Who thought to divine a cosmic plan
To unify the hearts of man
And make whole, concepts deep and grand.¹⁷

In March 1993, Salam's co-recipient of the 1979 Nobel Physics Prize, Professor Steven Weinberg and some other colleagues organized an international conference to honor Abdus Salam on his retirement as Professor at the Imperial College, London. Scientists from thirty-two countries were brought together to honor a man who is universally recognized as "one of the main architects of modern fundamental physics" and "who has devoted all his active life to the development of science around the world." I present below a sampling of some of the comments on Salam as a scientist gleaned from the technical papers published as the landmark, *Salamfestschrift: A Collection of Talks from the Conference on Highlights of Particle and Condensed Matter*, edited by A. Ali et al (Singapore: World Scientific, 1994).¹⁸ It is an excellent source for understanding different dimensions of Salam's own scientific work and the new avenues he opened for others. In the opening chapter of the book Weinberg acknowledged that as a graduate student he had spent a "fair fraction of his time in mastering Salam's analysis of overlapping ultraviolet divergences, and then as a post-doc at Columbia in using Salam's result that renormalization makes all integrals and all subintegrals however chosen superficially convergent, to show that the integrals actually converge."

In the words of Professor Zichichi of CERN, Vienna: "One of the most important and original contributions to the advancement of physics is the invention by Abdus Salam of Superspace. The unification of all forces of Nature being his great dream. ...The Einstein four dimensional Space-Time has

¹⁷ For the complete text of the poem see p. 451 in this volume.

¹⁸ See Chapter 63 in this volume.

developed into a Superspace where the number and the properties of the original dimensions is now 10-bosonic plus 32-fermionic. These frontiers of Physics are dominated by the Salam dream of the Superworld."

Professor Kibble of the Imperial College of Science wrote in his paper that Salam made many important contributions to unraveling the symmetries but this was not his first love: "His real goal was always to find the ultimate theory that would describe the weak, electromagnetic and strong interactions, and even gravity – what we would now call a theory of everything. Discovering the symmetries provided important clues to this theory, and was therefore more of a means than an end in itself." In the later part of his research paper, Kibble added: "And, of course, Salam went on to even greater unification, for example in his work with Pati on lepton-hadron unification and with Strathdee on supersymmetry and superfields and on Kaluza-Klein theory. I could mention many others. ... It was a tremendous privilege to be part of the team led by Professor Abdus Salam, and to participate in this voyage of discovery."

3.3 Salam as builder of international institutions. The naming of ICTP after Abdus Salam was the historic occasion when some of the finest tributes were paid on this important aspect of his personality. The first anniversary of his death, November 21, 1997, was celebrated as the Abdus Salam Commemoration Day by his colleagues, students and dignitaries from around the world. I have included excerpts from some selected presentations on the occasion as Chapter 71 in this volume, but a few memories of Salam as an international institution builder deserve our attention here.

Dr. M.A. Virasoro, who succeeded Dr. Salam as the Executive Director of the Centre, wrote in his Foreword to the published volume¹⁹ that the selected tributes were "a modest token of our admiration for all the works of Abdus Salam and of our gratefulness for the magnificent legacy he has left to this and to future generations." Salam was an acknowledged master in his field of specialization, as well as an outstanding communicator with political leaders of our time that helped him develop ICTP to the exemplary level of excellence in such a short time. Dr. André-Marie Hamende, a senior staff member of ICTP, who edited the volume of presentations at the memorial meeting, wrote that Salam was "a mature cosmopolitan personality" and he was honored to work with him for thirty years (1964-94). The most impressive quality that was at the root of his great success as the head of ICTP and other organizations he built or helped in developing was his, in Hamende's words, "multi-tasking capacity: he could switch from one subject to the other with the velocity of lightning." Luciano Bertocchi, who was one of Salam's closest associates for nearly twenty years and served as Deputy Director of ICTP, recalled that it was a period of extreme hard

¹⁹ *A Tribute to Abdus Salam: Commemoration Day 21 November 1997*, edited by A.M. Hamende, Trieste, Italy: The Abdus Salam International Centre for Theoretical Physics, 1999. [The Abdus Salam Memorial Meeting, 19 to 22 November 1997]

work, of initiating and laying foundations of fascinating new projects, but also of severe problems because of financial difficulties that often brought the Centre almost to collapse, but Salam was always able to pull everything through because he was "a man of great humanity, although this aspect of him might have been hidden by his energy, by his will to do more and more and to request the same from those who were working for him." There were two qualities of Salam that impressed Bertocchi above all others: his capacity of going straight to the heart of the problem and his great enthusiasm to explore new avenues and launch new projects, even when he was not sure of success.

Dr. M.H.A. Hassan from Sudan, Secretary General of the Third World Academy, who was very close to Salam since 1974 at ICTP and from 1983 onward as Executive Secretary of TWAS, and Dr. Hassan Dalafi from Iran, who put together Abdus Salam's *Renaissance of Sciences in Islamic Countries* (1994) expressed their special appreciation of Salam's "passion for the rejuvenation of science in the Islamic world – once a bastion of innovation and creative impulse". They call him "the greatest scientist in Islam since Ibn al-Haitham and Ibn Sina" and highlight what the famous science writer Nigel Calder called "Salam's cosmic anger" at the frail base of science and technology in the Muslim societies today as they waste millions on wars and political conflicts, while their economic, scientific and technological structures remain locked in imitation. Salam made several well-planned proposals and took steps toward the establishment of the Islamic Commonwealth of Science, and the creation of the Islamic Science Foundation, to move toward a hopeful tomorrow contingent upon five basic preconditions: "passionate commitment, generous patronage, provision of security, self-governance, and internationalization of the scientific enterprise."

What impressed Luciano Fonda of the University of Trieste most in Salam's personality was his deep sense of history, especially Islamic history, Islamic civilization, and the teachings of the great Islamic philosophers, which were "imprinted in his bones". Salam had given him and John Strathdee the responsibility of endorsing his checks of personal donations to individuals and institutions without making him conspicuous.

Prof. J. Song, Chairman of China's Science and Technology Commission, was among many who admired Salam's wholehearted devotion to the promotion of science and technology in the world, reflected, above all, in the founding of ICTP and TWAS and their affiliated organizations, that won him the admiration from all over the international scientific community.

Everyone who worked with him recognized that Salam was an equally passionate admirer of great men of science and knowledge across cultures and ideologies who were devoted to the welfare of all human beings. For example, Chapter 39 in this volume shows Salam's reverence for the Hispano-Jewish, multi-talented, scholar Maimonides (1135-1204), often called "The Moses of his time" who had assimilated the best of Greco-Islamic knowledge and "laid the

foundation of Jewish preoccupation with modern Science." Salam as a mathematician was greatly impressed by Maimonides' far-reaching thesis in his *Dalalat al-Ha'irin* that there are concepts that can be proved mathematically without our ability to conceive them. But he was most inspired by his belief that "human perfection is inseparable from knowledge, that the acquisition of knowledge is one of the highest forms of religion, and that man must be good before he can be wise." Salam wanted to establish many scientific institutes around the world so that the coming generations could be educated in line with such great benefactors of humanity.

Salam was deeply interested in helping women scientists to acquire the best possible facilities to shape the future of humanity on more humane lines away from nuclear armaments and other disastrous military ventures. Dr. Lydia Makhuba, President of the Third World Organization for Women in Science (TWOWS) with headquarters at the ICTP campus in Trieste – one of the several international institutions Salam initiated and helped build up – remembers him for his dedication to the uplifting of women in science, for the unique contribution that women scientists can make in focusing science to address the basic needs of humankind. In her words, Salam appreciated the "need to help women transcend socio-cultural barriers and join the international scientific community ... to improve the quality of human life. His ideas on this subject will remain a crucial cornerstone in all endeavors by women scientists to participate fully in the advancement of science and, more so, in those scientific pursuits which aim at improving the lot of humankind."

In going over the vast number of Salam's papers, I came across some important articles and notes on the general subject of World University and the United Nations University (UNU). I have included four of them as Chapters 12, 14, 16 and 17 in this volume, and there are several places in this volume where he discussed his ideas on the creation of these institutions. Without over-emphasizing his role in the creation and development of UNU, I must say that in December 1967, U. Thant, UN Secretary General (1962-72), told me during our meeting:²⁰ "Your country-man Dr. Abdus Salam, because of his experience as the Founder-Director of ICTP, deserves credit for helping us with ideas on the creation of United Nations University. Pakistan must be very proud of men of the caliber of Professor Bokhari and Professor Salam." U Thant formally proposed the idea to the UN General Assembly in September 1969, leading to the adoption of the Resolution by the UN General Assembly in December 1972 and the request to the next Secretary General Kurt Waldheim to appoint a Founding

²⁰ In connection with my in-preparation book on the late Professor Ahmed S. Bokhari, UN Under Secretary General. (*On This Earth Together: Ahmed S. Bokhari at UN, 1951-1958*, ed. by Anwar Dil. Foreword by Ralph J. Bunche, Nobel Peace Laureate. San Diego, California/Islamabad, Pakistan: Bookservice/Intercultural Forum, 1994.)

Committee of twenty experts from different disciplines and countries to draft the Charter of UNU. Dr. Andrew Cordier, former UN Under Secretary General, who was at the time Dean of International Studies at Columbia University, was appointed Chairman of the Founding Committee. The Secretary General in his opening statement to the Committee said:

Dissemination of knowledge, exchange of academic personnel, and the generation of catalytic ideas would constitute the central functions of the University. Consequently, most of the scholars may be expected to participate in the network's activities in a rotational, rather than permanent basis. It is felt that the problem of the "brain drain" which afflicts many of the developing countries, will be at least partially alleviated when the scholars keep their positions at their national universities and research centres and visit units of the United Nations University periodically in a system of "dual appointments."

Dr. Harold Taylor, Chairman of the National Council of Peace Strategy and a prominent American educationist member of the Committee, told me that it reminded him of lines from one of Salam's memoranda on UNU. During my meetings with Dr. Cordier in connection with the Bokhari book he also expressed his admiration of Salam's devoted work for establishing UNU and gave me copies of Salam's "The Advancement of Science for the Developing Nations" (Chapter 12) and "Memorandum on a World University" (Chapter 14). The United Nations University was approved to be established early in 1973 and Salam continued to advise and evaluate its various programs and projects right to the end of his active life. In November 1996, Dr. Heitor Gurgulino de Souza, Rector of UNU, called Salam's death "a great loss for the United Nations University, for he had not only been involved in its establishment but had also acted as Chairman of its Advisory Committee for many years."

Salam was able to initiate and participate in the creation of these and other institutions because of some very special personal qualities. One in particular was identified by Professor John Ziman of the University of Bristol, who admired Salam for his "diffusion of the delight, the marvels, the beauties, the pressures of the great discipline in which we were engaged". He saw Salam's extraordinary power of persuasion as the secret of his great success as a planner and builder of scientific institutions around the world, and called him "a magician in getting anyone to work with him in realizing his mission." For example, during his visit to Peru in February 1980, he asked his friend Dr. Victor Lattore to get together local scientists and engineers, especially those associated with the Atomic Energy Commission, to discuss what they could do to raise the GNP of the country. He advised them to develop their mineral industry by getting in touch with Australian miners for perforating rocks with electron accelerators. During his visit to Cusco, on the way to Machu Picchu, he met the Rector of Cusco University and planned with him a summer school that was, as a result, established as Multiciencias and is functioning admirably.

Julius Nyerere, Former President of Tanzania, with whom Salam worked in the South Commission, said it best: "He was a man of great simplicity of character, demanding nothing for himself except a chance to serve what he believed in." And Dr. Hans Blix of Sweden, who greatly admires Salam's vision to build international institutions, has written: "During my sixteen years as Director General of the International Atomic Energy Agency, I had many opportunities to meet Abdus Salam in Trieste and in Vienna and for admiring his brilliant intelligence, his innovative way of attacking problems, and his unyielding energy."

3.4 "*O Lord, work a miracle.*" In 1994, Salam received a copy of Mary Joseph's *Great Scientists: Abdus Salam* (New Delhi: Learners Press, 1994), a small book for little children with a dozen or so cartoon-like colored sketches highlighting his growing up in a family of humble means and through concentration on his studies and scientific research achieving outstanding academic distinctions. What pleased Salam most was the author's emphasis on the following to inspire children:

Abdus Salam had now become a famous man. ... "It is a sense of humility that leads most scientists to the truth, and it is a sense of wonder that leads them to a Superior Being," said Salam, as he sat in his office at ICTP, talking to a group of Asian students. On the wall, in front of him, was a framed inscription of a prayer. *Lord, work a miracle*, it read. Pointing to it, Salam said to them, "This is my reminder of the power of miracles, provided one sets them going with hard work."

Two books of his writings were published that year: *Selected Papers of Abdus Salam*, a compendium of his scientific papers, edited by A. Ali, C. Isham, T. Kibble, Riazuddin; and, *Renaissance of Sciences in Islamic Countries*, edited by H.R. Dalafi and M.H.A. Hassan, supplementing his earlier volume of general essays *Ideals and Realities*. In the shelves in his room were several revised versions and translations in a number of international languages of his *Science and Technology: Challenge for the South*, and his other books.

It is possible that in a moment of reflection on how far he had come in his work memories of a series of what he liked to call "little miracles" might have flashed on his mind: the creation of ICTP in 1964 and TWAS in 1983, as well as the Third World Organization for Women in Science (TWOWS), and the Third World Network of Scientific Organisations (TWNISO). All were located as he desired at Trieste, the proverbially beautiful meeting place of the East and West and the North and South, and all of them carrying on the mission of his life. He could not believe that only a few months back in April, another great dream of his had also come true: the inauguration in his homeland of COMSATS – the Joint Commission on Science and Technology for Sustainable Development in the South with headquarters in Islamabad.

This was the time that his disease, active since 1988, started debilitating his bodily functions. But luckily his mind was as clear and creative as ever. In fact,

Salam was in the midst of applying the principles of physics and mathematics to biology and hoping to find new insights into the nature of life. It is amazing that he kept reading and writing right to the end of his days in 1996. Professor Sergio Mascarenhas of the University of São Paulo, Brazil, has recorded the following: "When I last saw him in Oxford he was very ill. Holding his trembling hands, I could still see in his eyes that incredible shining glitter that made his presence unforgettable to everyone who had the privilege to meet him personally and to be inspired by him."

4. *Concluding Remarks.* I would like to go back to the time when Abdus Salam was a little boy and used to begin his school day by singing with his classfellows the famous Urdu prayer by the poet-philosopher Muhammad Iqbal (1877-1938) who was to become one of his guiding lights.

*Lab pih aati hay du'a bun ke tamanna meri
Zindagi sham'a ki surat ho khudaya meri
Dur dunya ka mere dum se andhera ho jaae
Har jagah mere chamakne se ujala ho jaae
(My life's aspiration comes to my lips as prayer,
May my life be like a candle,
May my life make the world's darkness melt away,
May my light make every place sparkling bright!)*



The 13-year old Salam was asked by his 9th grade teacher to write an essay on the first death anniversary of Iqbal. The original "Iqbal Meri Nazar me" (Iqbal in My View) is reproduced in this volume (p. 626) from his school notebook. It shows his great admiration, and is written in the classical Urdu style of the masters of Urdu literature. The great philosopher-poet, who also hailed from the Punjab, became Salam's role model. Like Iqbal, he went to study at the Government College, Lahore, where Professor Ish Kumar of the Department of English, a great lover of Iqbal's genius, inspired him to study Urdu, Persian and English works and memorize gems like the following Persian couplet:

*Talabum nihayat-e aafi kih nihaayat-e na daarad
Ba nigaah-e naa shakebe ba dil umeed daare
(I am searching for the ultimate that has no ultimate
New vistas with ever searching eyes and a heart full of hope)*

Salam devoted himself to personalize Iqbal's vision of *Insaan-e-Kaamil* (The Ideal Human), inspired by Self-affirmation, Self-expression, and Self-development, to make one's Self as perfect as possible, at the same time contributing his best through devoted Selflessness and Self-transcendence for the development of others in the human family, because one's truest Self achieves fulfillment only in society.

23. Muhammad Iqbal

Salam was always fond of quoting Iqbal's own words on the subject: "We are gradually traveling from chaos to cosmos and are helpers in this achievement. Nor are the members of the association fixed; new members of the association are ever coming to birth to co-operate in the great task. Thus the universe is not a completed act: it is still in the course of formation. ... The process of creation is still going on, and man too takes his share in it, in as much as he helps to bring order into at least a portion of the chaos." This forward movement of the simultaneous cultivation of Selfhood by acquiring knowledge and wisdom and Self-transcendence by giving one's best to others can be possible only if, in Iqbal's words, one is fortified by *Ishq* (Love) in the sense of the creation of unifying ideas and relationships and working toward a world of peace and progress for all.

Dar 'amal posheeda mazmoon-e-hayaat
Lazzat-e takhleeq qanoon-e- hayaat
 (Work for adding new extensions to Life
 To delight in creation is the Law of Life!)

This is the vision of Iqbal that inspired Salam and that is why he once said that he was an "*adna khaadim of Iqbal*" (a humble follower of Iqbal). He certainly followed Iqbal's mission of bringing the domains of Faith and Reason together in human personality with the unshakeable conviction that "the day is not far when Religion and Science may discover hitherto unsuspected mutual harmonies." Another role model for whom Salam used similar words of indebtedness in November 1992 at the Fourth Annual Conference of The Third World Academy of Sciences (TWAS) in Kuwait, was Sir Syed Ahmad Khan (1817-1898), the great transformational leader and founder of the Aligarh Muslim University in India.

Of course, there were others across time and space who were his role models and about whom he has written admiringly in his essays in this volume. What is important is how he assimilated the diversity of their knowledge and wisdom to make his personal and professional life rise to the world stage and earn epithets like the following: "one of the physicists that changed the world"; "Faraday and Maxwell would have been delighted with his achievement"; "modern day Einstein"; "one of the greatest men of our time"; "his life and work will continue to inspire generations of young scientists not only in the developing world but all over the world."

It has been a privilege for me to have known Professor Abdus Salam and a most rewarding experience to work on this volume in my "On This Earth Together Series." He knew that I was working on this book, and he liked the idea of dedicating it to his "inspirational role model" – Muhammad Iqbal.

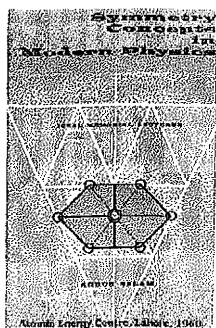
San Diego, California
 March 17, 2008

**PART I. SELECTED WRITINGS
BY ABDUS SALAM**

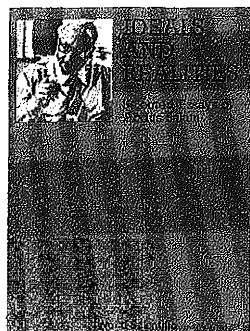


24. Abdus Salam, 1962

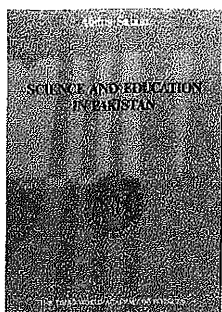
25. Title Covers of Some of Abdus Salam's Books



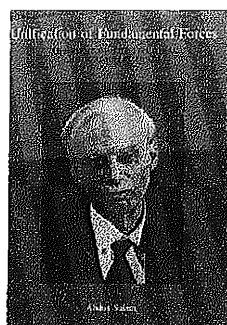
Symmetry Concepts in Modern Physics
(1966)



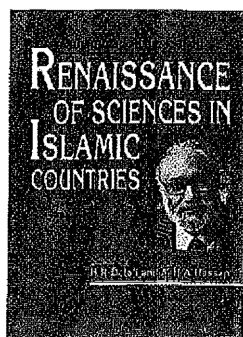
Ideals and Realities: Selected Essays of Abdus Salam (1984)



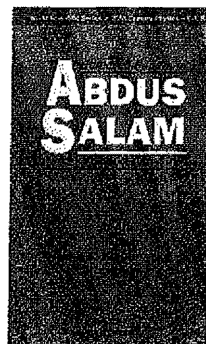
Science and Education in Pakistan
(1987)



Unification of Fundamental Forces
(1990)



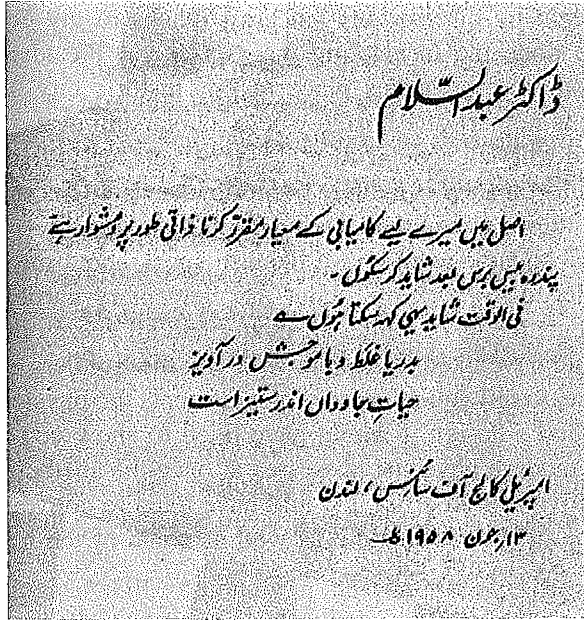
Renaissance of Sciences in Islamic Countries (1994)



Selected Papers of Abdus Salam
(1994)

1

My Concept of Successful Life



It is indeed difficult for me to establish the standards of success in life. Maybe I will be able to do so in the next fifteen or twenty years.

At this moment perhaps I can only say this (in Iqbal's words):

Badarya ghalt o ba mojash dar avez
Hayaat-e javidaa'n andar satez ast

(Rise, and grapple with the waves!
Life immortal is in daring struggle!)

Imperial College of Science
London,
June 13, 1958

— Written for and first published in *Kaamyab Zindagi ka Tassawur* [Urdu. Concept of Successful Life], edited by Anwar Dil and Shamim Younas, p. 140. Lahore: Maktaba-e-Jadeed, 1964.

2

Technology and Pakistan's Attack on Poverty

I wish to begin by offering my sincerest thanks to my colleagues for the honor they have done me in electing me as General President. I feel doubly proud because our meeting takes place in this historic city of Dhaka. In my experience there is no part of Pakistan where scholarship in its own right carries more esteem, and where a scholar receives more personal affection than in East Pakistan. This unfortunately is a dying tradition elsewhere but one which lives in Dhaka and I would like to begin by paying a tribute to this.

In my address today I would have liked to speak about the scientific field I have been privileged to work on, about the elementary particles of physics – those ultimate constituents of which all matter and all energy in the Universe is composed. I would have liked to explore with you the frontiers of our knowledge and our ignorance, to tell you of some of the concepts the physicists have created to comprehend God's design. I would have liked to show you that with all his pragmatism, the modern physicist possesses at once the attributes of a mystic as well as the sensitivity of an artist. I would have liked to convey to you some of the wonder, some of the fascination, as well as some of the heartbreaks of the physicist's craft.

But I shall not do this. In electing to speak on a general subject like "Technology in Relation to Pakistan's Attack on Poverty", rather than on Elementary Particle Physics, I am following the illustrious tradition of my predecessors in this office. More particularly, I have in mind the eloquent Presidential Address on "Technology and World Advancement" delivered by Professor P.M.S. Blackett to the Dublin meeting of the British Association for Advancement of Science in 1957. If I speak part of the time about the laws of economics rather than the laws of quantum physics, it is because like Blackett, I interpret Technology not in its narrow industrial sense but as something embracing the scientific organization of most modern life. There are times when, in all humility, a mere scientist may also express himself on ideological matters, not because he has new insights to reveal but because there are things he believes passionately in, which need saying and cannot be said often enough.

We in Pakistan are very poor. This poverty we share with the majority of the

Address as President of the XIII Annual All Pakistan Science Conference held at Dhaka, January 11, 1961.

human race, with some one thousand million people in about a hundred countries. Fifty percent of us in Pakistan earn and live on less than eight annas [half a rupee] a day; seventy-five percent live on less than a rupee. This rupee a day includes the two daily meals, clothing, shelter and education, if any. In contrast, some four hundred million inhabitants of Europe and North America live on an average daily income of fifteen rupees.

It is important to realize that this uneven distribution of wealth is of a relatively recent origin. Three hundred and fifty years back, Akbar's India and Shah Abbas' Iran compared favorably in living standards with Elizabeth's England. Soon after, however, the Western growth started. It coincided with a great technological advancement in agriculture and manufacturing methods. New technical advances on a limited scale have occurred from time to time in the history of human societies. These advances have always led to increased prosperity. What, however, distinguished the nineteenth century technological revolution was the fact that it was firmly based on a scientific mastery of natural laws. This gave man so much power, and it has led to so great an increase in production, that for the first time in human history, there is no physical reason for the existence of hunger and want for any part of the human race.

The realization that hunger, ceaseless toil and early death can be eliminated for whole societies, and not merely for parts of societies, is something new. The last hundred years have seen nation after nation start with something like our conditions and crash through the poverty barrier. The laws governing this type of transformation are now well understood. First, a society must acquire the requisite technological skills; secondly, it must save and re-invest more than five percent of its national income to productive enterprises. This minimum of five percent just offsets the depreciation of existing wealth. To double the standard of living in forty years an investment rate of 10-15% is needed; to double it in a decade, a nation needs to invest about 25% of its national income.

Skills and capital – these then are the two pre-requisites for building up a self-reinforcing economic growth. Nation after nation has achieved this in the last two centuries, each nation leaving the imprint of its own peculiar experience. Four of these experiences – those of Britain, Japan, Russia and China – however, stand out clearly. The British were the first to show that the poverty barrier can be crashed through if skills and capital are available. The Japanese showed that Technology is communicable; that it is easy to learn and acquire. Having been conditioned for years to look with misty, uncomprehending eyes at the engineering miracle of an airliner, I still remember the shock of my life when I first visited the De Havilland Aircraft Factory at Hatfield. Instead of an organized assembly line where I expected to see molten aluminum being poured in at one end and a Comet Airliner coming out at the other, all I saw was something like an overgrown metal-smith's workshop in rural Pakistan. And when two women in overalls lifted a couple of aluminum sheets while a third started welding them together with a manually operated welder to make part of the fuselage, I am

afraid I lost my respect for the mysteries of the manufacturing craft. I do not for one moment wish to suggest that all technology is electrical welding. There is the other part of the story – the aerodynamic design of the Comet where the high-level scientific talent comes in. But the Japanese experience forced home the moral that technological competence is not a hereditary characteristic; that it can be acquired and in fact acquired rather quickly. The third important lesson came from Russia. It showed that transition to sustain growth need not take a century or longer. It can be telescoped into the span of one man's life provided heavy industry receives top priorities. And then finally there is the Chinese experience, underlining that cheap labor is itself a form of capital.

Summarizing the economic part of our argument, skills and sufficient capital rightly invested are the major ingredients of self-reinforcing growth. On the road to achieving sustained, compounded growth of this type, all nations have left the imprints of their peculiar experience, but four stand out clearly: the British experience, showing that it can be done; the Japanese experience, that technology is easy to acquire; the Russian experience, that priorities on heavy industry accelerate the growth; and the Chinese experience, that cheap labor is itself a form of capital.

From this brief and highly idealized economic summary, let us turn to the realities of the situation in Pakistan.

The facts of our poverty are obvious enough and I am not going to mince words about it. You can go out in the streets and see it all around you. I am not referring now to the obviously shelterless, the obviously needy. I have in mind more the uncomplaining millions, with their suppressed hunger, the millions who, and I speak from experience, seldom get the two regular meals of the day; the millions who must often choose between buying badly needed food or a book for their schooling children. We live with a crushing poverty of the sort which Europe or America has not seen since the day when Dickens wrote. The marvel to my mind always is that the human spirit does not break and that most of the needy are still able to keep a dignified exterior.

The sense of what can be achieved, on the other hand, hits you most when you visit an affluent society like that of the United States. You just cannot believe the plenty – the plenty not for the few but for everyone. Every time I am privileged to visit that great country, I have to remind myself afresh that it is indeed possible to produce so much for so many.

I do not say all this in any spirit of envy. This prosperity is due to an organization of society where scientific knowledge is fully exploited to increase national productivity. This prosperity is a portent of hope; hope that possibly within our lifetime, using the same methods, we in Pakistan may also achieve the same.

Our poverty raises not merely material but also spiritual issues. The Holy Prophet, may peace and blessings of Allah be upon him, said, "It is near that

poverty may become synonymous with *kufr*." I shall not attempt to translate *kufr* into English; the nearest equivalents, apostasy or unbelief can never convey the connotations, which *kufr* has for a Muslim audience. Let me say with all the vehemence at my command that I would like to see this saying of the Prophet on the door piece of every religious seminary in Pakistan. There may be other criteria of *kufr* as well, but in the conditions of the twentieth century, in my opinion, the most relevant criterion of *kufr* is the passive toleration of poverty without the national will to eradicate it.

I have mentioned technological skills and capital as the two prerequisites before a pre-industrial society like ours can crash through the poverty barrier. Actually there is a third and even more important prerequisite. There is the national resolve to do so. In Professor Rostow's words, "a nation's take-off into sustained growth awaits not only the build-up of social overhead capital – capital invested in communication networks, schools, technical institutes – it not only awaits a surge of technological development in agriculture and industry, but it also needs the emergence to political power of a group prepared to regard the modernization of the economy as a serious high order political business." Such was the case in Germany with the revolution of 1848; such was the case with Japan with the Meiji restoration of 1868; such was the case with the Russian and Chinese revolutions. Our independence in 1947 could have provided us with the necessary stimulus. Unhappily this was not the case. Our independence did not – definitely did not – coincide with the emergence of a political class which made economic growth the centerpiece of State policy. I can still recall the interminable arguments, conducted in private and public, in the early years of Pakistan, about its ideology. Never in these discussions did I hear the mention of total eradication of poverty as one of the primary ideological functions of our new State.

True enough, the country registered commendable progress in the manufacture of consumer goods – though, one must not forget, with appalling suffering to the consumer himself. True enough the establishment of the Pakistan Industrial Development Corporation was a triumph. But at no time was this development purposefully designed to achieve the breakthrough we have talked about. The First Five-Year plan was commissioned in 1955, a full eight years after independence. It did not receive formal approval of the government till 1957. During those years there was a total neglect of the primary sector of our economy – agriculture; we squandered the windfall surpluses of the Korean War boom in buying, on Open General Licenses, European cosmetics and radiograms. It is not only that we failed to develop basic heavy industries, we did not even make any provisions for their future establishment; not even to the extent of starting to get our men trained in basic technologies. And, lastly, we completely neglected the exploitation of our minerals. Not even a survey was undertaken.

It would be right to date our progress to the "take-off" from the assumption of power by the present Government. I believe when the future history of Pakistan is written, the greatest significance of the revolution of 1958 will come to be recognized as the resolve for the first time of Pakistan's Government to achieve the breakthrough within five years. This resolve is reflected first by a recognition of the need for bold planning for agricultural development, for exploitation of minerals and most important for all, for heavy industry. Secondly, it is reflected in the recognition that a liberal provision for developing technological and scientific skills is the wisest investment a nation can make.

Take our new Five-Year Plan first. It is a sagacious plan though perhaps not as audacious as I would like to see. It aims at achieving the crucial 10-15% investment level. It places due emphasis on our primary sector of agriculture. It envisages the beginning of a basic heavy industrial complex, particularly the steel industry. And, most importantly, it sets about exploiting our one industrial source material – the Sui and Sylhet gas – to set up a petro-chemical industry.

Quite often one hears abroad the rather sneering statement that underdeveloped countries look upon steel mills as national monuments. I personally confess to this complex, and for very good economic reasons. Without a heavy industrial base, nothing is possible in the long run. To take one pertinent example given by Professor Mahalanobis (the great Indian statistician) let us consider the problems of providing 700,000 tons of extra grain needed for the five million annual increase of Indian population. There are four ways of getting this extra grain: buy the grain; buy fertilizer to grow the grain; buy plants to make fertilizer; or finally build heavy engineering capacity capable of making fertilizer plants. The cost of buying grain works out at 300 million pounds; the cost of buying fertilizer is one-third of this, and the cost of fertilizer plants about one-fourth. But the real saving comes if one sets up heavy manufacturing capacity to make fertilizer plants. The cost then is just some ten million pounds. If the last alternative is chosen, one must however start planning some eight or ten years in advance of the season in which the fertilizer would be used.

It is gratifying that so far as fertilizers are concerned, our planners have chosen the third alternative. We are not planning to buy fertilizer but we shall make it in the country. Personally, of course, I would strongly favor Mahalanobis' last alternative – to set up the heavy manufacturing capacity within the country to make fertilizer machinery. The Second Five Year Plan has made a beginning toward this by contemplating steel production of 400,000 tons. As steel producers and consumers it will put us in the same world class as the Republic of China and though I cannot say I feel satisfied with this, it is at least a beginning.

Turning again to the question of 10-15% capital investment needed for achieving the economic breakthrough, there is a vital 3%, which must be provided for in Foreign Exchange to buy foreign goods, foreign machinery and foreign know-how. It is this crucial 3-4%, which must come from the advanced

countries either in the form of long-term loans or outright gifts. During 1957-58, some two and a half billion dollars were provided by the USA, UK, USSR and France as aid to underdeveloped countries. Let us make no bones about it; this gift entails sacrifices for ordinary people like us in the donor countries. In the United States, stores always show prices without the Federal Tax. The tax is added on at the counter so that one is highly conscious of the extra imposition by the time the purchase is completed. Thus whenever I have had to pay the ten cents of Federal Tax while shopping around, the thought that at least a quarter of a cent was going into foreign aid lightened the burden for me. It also gave me added respect and admiration for all those who constantly make this sacrifice.

The economists have estimated that in order that this aid brings its fullest impact, it must be stepped up from two to at least three billion dollars annually and kept at this level – with a guaranteed continuity – for a very long time to come. To get the scale right, it is perhaps worth mentioning that the Marshall aid to Europe just after the War ran to about twice this figure, though of course the rapid recovery of Europe made its continuance unnecessary after three years.

As I said before, the aid is a gift and it necessarily entails sacrifices and there is very little we can offer in return – at least for a very long time. Whether it will or will not be forthcoming is in the end a moral and spiritual question. I can only quote sages like Rostow who has spoken of “the resources of spirit, will, and insight which the West needs, quite as much as steel and electric gadgets, to do the jobs which extend not only to missile arsenals and the further diffusion of welfare at home” but to the Five Year Plans of the nations abroad. I can only quote Blackett when he speaks about “the uneven division of wealth and comfort among the nations of mankind, which is the source of discord in the modern world, its major challenge, and unrelieves its moral doom.” I do not know if a future historian will find it ironic that in the 1960s, three billion dollars of aid were not easy to find while sixty billion dollars were annually spent stocking the world arsenals with atomic weapons, missiles and rockets. And I find it strange that during 1957-58 while underdeveloped countries received 2.4 billion dollars in aid, they lost two billion dollars in import capacity – in getting paid less for the commodities like jute and cotton which they sell and in paying more for the industrial goods which they buy. Paul Hoffman calls this a “subsidy or contribution by the underdeveloped to the industrialized countries” – a subsidy which almost washed away the entire sums received in aid. And as a physicist, I find it the height of hypocrisy to pretend that the man-made satellites orbiting in space and each costing at least as much as the entire yearly budget of Pakistan have been sent up only to collect data on cosmic rays. All this makes no sense. It all points to one thing: the bankruptcy of world statesmanship in dealing with problems of hunger and want. Dare I say that what the world needs today is a great successor to Keynes to preach on a global scale that the raising of living standards of any depressed region is a collective world responsibility. Dare I say

that we need a great successor to Roosevelt to give a New Deal not simply to one part of the United States but to a large part of the human family.

I have talked so far about our plans and the position regarding capital. I now wish to turn to the question of the provision of technical skills. And this is where we as scientists directly come in.

Nowhere more than in this respect can we see the force of my remarks regarding the recent change of climate in Pakistan. This change is embodied particularly in the work of Education and Scientific Commissions.

Consider first the category of technicians who understand the scientific foundations of their craft. It is an awful fact but nevertheless true that in the entire liberal arts-dominated educational history of British India, there never was anything analogous to the British National or Higher National Certificates in Technology. I could not believe it when I was first told that Great Britain had three hundred colleges of technology spread all over the country training 30,000 technicians every year. One of the most far-reaching recommendations of the Pakistan Education Commission is the provision to establish enough technical schools and polytechnics to produce 7,000 technicians a year. Our major problem is the staffing of these technical institutions. I purred with pride last year when Sir John Cockcroft spoke to me about the excellence of our army technical school and their technical instructors. I am sure it will not be impossible to tap this reservoir for providing teachers in the early stages.

We in Pakistan are disposed to think of Scotland as a prosperous state within the British Commonwealth. I was startled the other day to read an article by Dr. J.M.A. Lenihan, entitled "What is wrong with Scotland?" After painting a rather gloomy picture of consistent economic decline, Dr. Lenihan concludes that this decline stems entirely from lack of trained technologists. To the objection that if there is no industry in Scotland, there is no need for technical colleges, Dr. Lenihan counters by remarking, "The scientist, the technologist and the technician are, in the main, products of the educational system, not of the industrial system in which they hope to work. A coherent demand for technical education facilities will not rise from an assortment of industries but the existence of technically trained people will facilitate the growth of new industries."

Dr. Lenihan's viewpoint about skills coming before industrialization has of course a peculiar relevance to our situation in Pakistan. Some ten days back I heard a similar comment from Professor S. Tomonaga, the great Japanese physicist, now President of Tokyo University. Speaking of the spectacular rise of the Japanese transistor industry, Professor Tomonaga attributed it to a careful cultivation of the art of calligraphy. Every Japanese child must spend years learning the calligraphic arts at school; this develops a sensitivity of touch, a nimbleness of fingers, a peculiarity suited as they have now discovered to

transistor assembly and development. Clearly no skills or special talents a nation may cultivate are ever wasted when the spark of industrialization comes along.

There is one other passage from Lenihan's address, which I would like to quote. After listing a number of difficulties which face Scottish economy, he goes on to say, "Many of the difficulties that have been mentioned are the natural consequences of living in a country" – that is Scotland – "where science is not taken seriously enough. How else can we describe a country which, fighting for economic survival in a world dominated by technology, allows the basic sciences of physics and chemistry only the status of half subjects in the school curriculum." There is perhaps, in Dr. Lenihan's remarks, a considerable moral for Pakistan's secondary education.

Perhaps the most depressed community, till recently, among technicians in Pakistan was – and so far as university teachers are concerned still is – the community of scientific workers. All scientific research institutes in Pakistan have been run under the uncomprehending bureaucratic control of Government Ministries. And when I say control, I mean control. We seem never to have recognized that in a science-dominated world there ever could be any tasks for Pakistani scientists. The official attitude towards Science has been at best one of reluctant indulgence, somewhat like the attitude of the learned divines in the worst and most intolerant days of the Bukhara Emirate towards the local clock-maker who was a Christian. He was permitted to enter the mosque for repairing the tower clock only on a plea that after all, in the matter of technical usefulness, he was on par with the donkeys, which carried the stone-slabs into the mosque in the first place. Why should the clock-maker suffer a greater social disability? Not only did our bureaucracy adopt the divines' attitude to the clock-maker but also, if possible, the clock-maker was hired from abroad.

One aspect of this neglect is the awful fact that there are so few of us in the country. According to the statistics collected by the Scientific Commission there is a total of sixty trained physicists in Pakistan. To get the scale right, this is roughly the number of correspondingly trained men you may find in any one London College. In scientific research, unfortunately, it is no longer possible for a single person to achieve his individual breakthrough. Before science can flourish and a scientific tradition can develop, there has to be a critical size, a critical number of trained scientists at one place. Once the critical number is reached, the chain reaction starts; the group becomes self-reacting. Otherwise it simply withers and dies away.

I have great hopes that all this is going to change. As you know a Scientific Commission was appointed by the Government last year, and it has presented its report. From the manner in which the government has reacted to reports of its previous Commissions, I venture to predict that 1961 may be the beginning of a new era for scientific research in respect of its organization, in respect of the massive training programs which may be initiated and in respect of the calls

which the nation may make on its scientific talent. In fact I have a feeling that the boot may soon be on the other foot. I only hope we, as scientists, can rise to the challenge and are not found wanting and unprepared.

What exactly are the tasks in which we as scientists can make an immediate contribution? One could list a number, ranging from problems of low-productivity in agriculture, problems of flood control and water-logging, to the optimum use of Sui-gas. To take one concrete example, a new method for gas-reduction of low-grade iron ore has been developed in Mexico. Most steel producing countries are of course not interested in gas-reduction for they possess plentiful supplies of coke. The Mexican process is producing one million tons of steel annually. Our situation in Pakistan is similar to that of Mexico. We possess gas as well as low-grade iron ore. It is gratifying that our Department of Scientific and Industrial Research has independently started a small development project for the process. If successful, it may revolutionize our steel economy. Would you not agree that the project needs topmost blessing and the highest priorities?

I would like to end by briefly reiterating some of my remarks. In hoping to achieve the breakthrough to national prosperity, we, like most other poor countries, depend considerably on numerous factors beyond our national control. But there are a number of internal prerequisites the nation must satisfy before the transformation of our society will take place. The first and foremost of these is the firing of the entire nation and harnessing of its spiritual energy, to the objective of eradication of poverty within one generation. This will need constant reiteration of the economic objectives; in particular this will need convincing the nation that the economic policies are designed to enrich the whole society and not merely a part of it. I do not know how the youth of Dhaka spend their evenings but as a measure of a nation's consciousness, I shall feel happy when Lahore, for example, makes a transition from its present literary to a technological culture and instead of love-lyrics in the Mall Cafes, that discussions range freely and fiercely – at least part of the time – over the targets of the Five Year Plan.

Let us be absolutely clear about the nature of the revolution we are trying to usher in. It is technological and scientific revolution and thus it is imperative that topmost priorities are given to the massive development of the nation's scientific and technological skills. And finally, let us, as scientists, face and live up to the challenge thrown up by Pakistan's poverty. Let future historians record that the fifth important lesson in economic transition to prosperity was taught by Pakistan in achieving a rate of growth as rapid as the Russian and the Chinese but without the corresponding cost in human suffering.

Let me end by quoting from the Holy Qur'an: "The Lord changeth not what is with a people until the people change what is in themselves." ۞

3

Need for an International Centre for Theoretical Physics

Two years back in September 1960 the Pakistan delegation had the privilege to co-sponsor the first resolution requesting the Agency to create an International Centre for Theoretical Physics. During these two years the idea has progressed; firstly by the most generous financial offers from the Danish and the Italian Governments to help in setting up such a Centre and secondly by the enthusiastic support the idea has received from the world community of physicists. The panel of physicists which was convened by the Director General in March 1961 whose report was circulated to member Governments enthusiastically endorsed the idea of the Centre; they defined its scope and objective and discussed the manner in which it could be set up and run. I shall be referring frequently to the conclusions of this panel.

In considering the question of whether the Agency should set up such a Centre, in the final analysis, there are just three questions we should ask ourselves: 1) Does research in Theoretical Physics fall within the scope of the Agency's activities? 2) Do physicists from the emerging countries really need and desire such a Centre? 3) If the Centre is desirable, can it be created and finally can the Agency afford it?

Let us examine the issue in the light of these three questions. First: *Does research in Theoretical Physics fall within the scope of the Agency's activities?* The submission of the sponsors of the resolution before us is that there are indeed fewer sciences, which have contributed more to the coming of the atomic age than theoretical physics. Even if we ignore the fact that Einstein was the first scientist to dream of equivalence of mass and energy and to create the whole basis of our science, even if we forget that two of the world's leading theoretical physicists, Fermi and Wigner, built the world's first atomic reactor, we dare not forget that there are still uncharted areas in theoretical plasma physics which are vital to the tapping of fusion power. We dare not forget that in spite of all our advances in nuclear physics, we still do not know the theoretical expression for

Speech delivered at the International Atomic Energy Agency (IAEA) Conference, Vienna, 1962.

the law of force between two nucleons. These indeed are areas in Theoretical Physics of direct and immediate concern to the Agency; with research in them its major responsibility. Let me name these areas again; these are reactor theory, plasma theory, low energy nuclear theory, theoretical high-energy physics. This last may sound on the very speculative side of theoretical physics. But I sometimes wonder what reply an Agency like ours may have given to a request of a young and perhaps unknown theoretical physicist, Albert Einstein in 1904, if he had made an application for a Fellowship to follow his theoretical speculations in the nature of space and time. Who among us would have dreamt that he would come up also in the same paper with the relationship of energy and mass? Who among us dare say today that a wild theoretical speculation on the nature of the μ -mesons may not be relevant to the energy problems of tomorrow?

My remarks about theoretical physics and its relevance to the Agency's activities are not to deny the role of other scientific disciplines, nor to deny the Agency's responsibilities to them. But as we shall see, the greatest claim theoretical physics has rests on one thing peculiar to it: theoretical physics needs no apparatus, it is the least costly of all sciences. The return relative to cost for this discipline is the highest. If the Agency has to choose among fundamental sciences on a tight budget, theoretical physics is undoubtedly the subject of choice to support in respect of the immense scientific prestige the results of the theoretical investigations would bring to the Agency as sponsors. The case for the Agency to support Theoretical Physics gets strong when we consider this subject from the point of view of the emerging countries.

First and foremost let us not forget that young scientists in the underdeveloped world feel the urge to meet the challenge of fundamental science as much as anyone else. Among the fundamental sciences, theoretical physics has a peculiar fascination for them: First, no costly apparatus is needed; second, in this field individual initiative – rather than large collaborative effort – can still lead to a breakthrough. Almost invariably theoretical physics is the first science in smaller countries, which gets developed at the advanced level. History bears this out; this was the case in Japan with Nishina and Yukawa; this was the case with India, this is happening now in Brazil, Turkey, Lebanon, and Argentina. No one can reverse the historical process of the order in which science grows in rich and poor soils. But in spite of the native ability, in spite of the ambitions of these scientists, they, in common with other scientists in their countries, suffer from one fatal disability – isolation. After an initial period of brilliant work at some active center, they are faced with a cruel choice; either to leave their countries or to ossify and become scientific administrators. Unlike other scientists whose disabilities may include lack of costly equipment and apparatus, the theoretical physicist can be helped at a very small cost, by making frequent contacts

possible, by awarding him frequent visiting Fellowships to live for periods at active centers.

Boiled down to its essentials, we are therefore talking of an extended Fellowship program. I believe up to this point a very large number of delegates are with us. I think the misgivings of some of the delegates start at this point, in the manner in which such a Fellowship program may be administered. The simplest manner to do this as suggested by SAC is to have a large number of Fellowships available at a selected number of regional or national centers like CERN, Copenhagen, Dubna and Princeton. Please notice that even if these Fellowships are given by IAEA, in view of the fact that the normal time for processing a Fellowship by an Agency is seventeen months, one would have to place these particular Fellowships at the disposal of the Centers we are talking about.

Now such a Fellowship program is fine. But its crucial weakness is, that there are not enough places in the existing centers to meet the demands for visiting these centers. This was emphasized by the panel of distinguished physicists – some of them from the centers mentioned. This has further been re-emphasized by the letters the Director General has received from CERN and Copenhagen. In effect, by creating the Centre, the Agency would be adding some fifty new places for visiting Fellows from the East, from the West and from the emerging countries to the world total now available with a strong orientation towards the last category.

I have mentioned the work of the panel of the theoretical physicists. This panel was attended also by a representative of UNESCO. On his authority, we believe, it is a fact that while UNESCO is deeply interested in such a Centre, by its Charter it is barred from creating it under its own auspices. An important question often asked is, will such a Centre lure the scientists from the emerging countries away from their homes. Our answer is an emphatic "No"; on the contrary, the Centre will help in stemming the torrent of migration. If one is certain of being able to spend periods up to six months or a year working on a research problem after every two or three years, the incentive to become an exile considerably decreases.

Finally, *do the physicists from the underdeveloped countries want such a Centre?* We have before us a document signed by fifty-three of the participants who attended the Seminar at Trieste. Twenty-five of these were first-rate men from smaller countries. Let me read just a line or two from their letters: "While important cross-fertilization of ideas has taken place during the six weeks of the Seminar, the Seminar has served to underline the need for a Centre – in order for important joint work to be done, contact for more than six weeks of a summer seminar is necessary. ..."

Let us turn now to the third point:

Is it scientifically possible to create such a Centre? Can one find three or four distinguished physicists who feel that they would make a more important contribution by joining this Centre as permanent staff? Would other distinguished men come to this Centre as visiting Professors? We humbly submit that the answer to these questions cannot be given by a debate at a meeting of the Board of Governors. The answer depends on whether the world community of physicists is enthusiastic about such a Centre. I can only give my personal impressions. I know for a fact that great men like Niels Bohr, Yukawa, Bethe, Weisskopf, Marshak, Schwinger, Pais, Infeld, to name but a few, are strongly in favor of an International Centre. No such Centre now exists; once it is created there are scores of activities it can engage on, like arrangements of Seminars, secondment of physicists for visits to smaller countries. Inevitably the Centre will become the clearinghouse for new ideas. With it is associated at present the idealism of the world community of theoretical physicists.

Finally, and most important, *can the Agency afford such a Centre*. For the capital expenditure we have two magnificent offers. The running costs relate mainly to Fellowships. From informal contacts again we understand that, in addition to the generous beneficiaries mentioned earlier, a number of private foundations may provide all the Fellowships necessary. It is our belief that the Agency will have to make a very small contribution, if any, from its own resources. The major aim of the resolution we are presenting is that the Board of Governors should make a serious effort to tap such sources before the idea of a Centre is condemned on financial grounds.

Gentlemen, let us project ourselves twenty years from now. The world is moving closer, economically, intellectually, scientifically. In twenty years, there will be international research centers not only for theoretical physics but for most fundamental sciences. The world trend is in this direction and nothing can stop it. It is possible for us in this Agency to take the initiative in forwarding this movement. I do hope very much we shall. With these words I commend to you the resolution in front of us. ■



26. Participants in the 1960 seminar that spurred the creation of ICTP; Abdus Salam (right), future Director, with Paolo Budinich, future Deputy Director

4

Diseases of the Rich and
Diseases of the Poor

Nine hundred years ago the great physician of Islam, Al-Asuli, writing in distant Bokhara divided his pharmacopoeia into two parts: "Diseases of the Rich" and "Diseases of the Poor". If Al-Asuli was alive today and could write about the afflictions of mankind I am sure he would again plan to divide his pharmacopoeia into the same two parts. Half his treatise would speak of the one affliction of rich humanity – the psychosis of nuclear annihilation. The other half would be concerned with the one affliction of the poor – their hunger and near starvation. He might perhaps add that the two afflictions spring from a common cause – the excess of science in one case and the lack of science in the other.

At least so far as the problem of world poverty is concerned, none will question the thesis that with man's recent mastery of science and technology there is no physical reason left for the existence of hunger and want for any part of the human race. I wish not so much to preach the virtues of a scientific organization of society, but to provide a necessary objective perspective to the practical problems of science and development.

I have always been puzzled by how few people among the richer nations are really aware of the intensity of world poverty. Contrasting the two ills of Al-Asuli, nuclear death and starvation, it is no doubt true that from Moscow or New York the possibility of ultimate nuclear annihilation appears grimly near. But in Khartoum or Karachi the living death of daily hunger is nearer still. Fifty percent of people in my country of Pakistan earn and live on eight cents a day. Seventy-five percent live on less than fourteen cents. This fourteen cents includes the two daily meals, clothing, shelter, and any education. To us, the unresolved conflicts of the East and the West appear as distant wearying conflicts, inevitable luxuries of a state of physical well-being. For us, the nuclear problem is tragic only in that it leads to a criminal waste of the earth's resources. For me personally it is tragic for it claims the last ounces of the strength of some of the greatest sages of our age – sages like Bertrand Russell – who may otherwise have preached the immediate crusade against hunger and want.

But why are we poor? Mostly no doubt through our own follies. But let me humbly suggest that it may partly also be that we are financing some of the

prosperity of the rich. Year after year I have seen the cotton crop from my village in Pakistan fetch less and less money; year after year the imported fertilizer costs more. My economist friends tell me the terms of trade are against us. Between 1955 and 1962 the commodity prices fell by seven percent. In the same period the manufactured goods went up by ten percent. Some courageous men have spoken against this. Paul Hoffman called it a "subsidy, a contribution paid by the underdeveloped countries to the industrialized world." In 1957-58, the undeveloped world received a total of \$2.4 billion in aid and lost \$2 billion in import capacity (through paying more for the manufactured goods it buys and getting less for what it sells), thus washing away nearly all the sums received in aid. I am sure that even a fully armed world with the largest possible stockpiles of armaments can forego further impoverishing the poor in this way. I am sure there are enough resources, technical and material, to cure the diseases of the poor even if the rich cannot agree to cure their own affliction.

But first let me make my premises clear. I am not referring to science as a way of life, only to the important roles of science and technology in raising living standards rather quickly. We must all realize that this is the science of an unglamorous variety. It consists largely of taking stock of a country's natural resources. It consists of the long process of acquiring some of the well-known technical skills. It consists of making an imaginative assessment of which of the resources can be technically exploited most expeditiously, within the human and the material means at one's disposal.

Unfortunately, in most undeveloped countries there are few men who can make the right lists of priorities. This is not because they do not know the needs; it is more because what science and technology can achieve is only very vaguely apprehended. The greatest single long-range contribution individual scientists can make is in helping to create such men. There is fortunately more that can be accomplished sooner.

First and foremost there is the need, in P.M.S. Blackett's phrase, for a "world supermarket" in science and technology, a comprehensive display in one place of what science and technology can achieve in raising living standards and at what cost. One of the finest initiatives to do just this has come from the United Nations Conference on the Applications of Science and Technology held at Geneva in February. The technical supermarket conference unfolded will, I am sure, make rational assessment of priorities easier.

But the problem does not end with a conference. Even after one knows what one wants and what one can afford, for a very long time to come developing nations shall have to rely on importing technology. The chief suppliers are technical firms of consultants and contractors. It is at this crucial stage of counsel and advice that the technical knowledge and the idealism of the scientist can help.

I have nothing against technical firms as such. Some of them have done superb jobs, particularly when their tasks were clearly delineated in advance. But by the very nature of their specialization, they are concerned with a narrow segment of development. And naturally enough, they do not possess the strongest of urges to help develop indigenous technical talent.

An example of an alternative possibility is one of the most valuable of scientific and technical ventures of recent times: the 1961 study of Pakistan's immense salinity and water-logging problem by a team of university scientists, agriculturists, engineers, and hydrologists from the US led by Roger Revelle. No consulting firm could ever have assembled such diverse talents; no commercial organization could ever inspire the same degree of devotion.

I do not know what international mechanism there exists at present for assembling missions like these. I wonder if it is too much to hope that the February UN conference may be followed by the creation of a permanent UN agency on applications of science and technology. I am sure collective thinking could devise such an agency or some other means to channel the immense reservoir of idealism combined with technical competence which many groups of scientists possess.

Earlier I alluded to the immensely more important task of helping to develop first-rate men in the smaller countries themselves. The only one way to do this is to build up a true scientific tradition there. By locating international research programs in the smaller countries, by awarding research contracts to their growing research centers, by visiting and by responding generously to their staffing requests, these incipient centers could be brought into the vigorous mainstream of science. This in the end will also bring economic salvation.

I have only very briefly touched on some of the ways scientists can help. To me, the greatest portent of hope is that men of science have begun to be interested in this problem in addition to nuclear disarmament. ▮

5

Pakistan and Technical Development

Three centuries ago, around the year 1660, two of the greatest monuments of modern history were erected: one in the West and one in the East. These were, respectively, St. Paul's Cathedral in London, and the Taj Mahal in Agra. Between them, the two symbolize, perhaps better than words could describe, the comparative level of architectural technology, the comparative level of craftsmanship, and the comparative level of affluence and sophistication, the two cultures had attained at the epoch of history.

But about the same time there was created – and this time only in the West – a third monument; a monument still greater in its eventual import for humanity. This was Newton's *Principia*, published in 1687. Newton's work had no counterpart in the India of Mughals.

It is my purpose, today, to lead you through the fate of the technology which built the Taj Mahal, when it came in contact with the culture and technology symbolized by the *Principia* of Newton.

The first contact came in 1757. Exactly one hundred years after the building of the Taj Mahal, the superior fire power of Clive's small arms had infected a humiliating defeat on the descendents of Emperor Shah Jahan. One hundred years more, and in 1857 the last of the Mughals had been forced to relinquish the crown of Delhi to Queen Victoria. With the last Mughal, there passed away not only an empire there, but also passed a whole tradition in art, in technology, in culture and in learning. By 1857, English had supplanted Persian as the language of state and learning. Shakespeare and Milton had replaced the love-lyrics of Hafiz and Omar Khayyam in school curricula, the medical canons of Avicenna had been forgotten and the craft of muslin-making in Dhaka had disappeared to give way to the cotton prints of Lancashire.

1857 is my index mark for another reason too. Around this year was laid the foundation of modern Pakistan – Pakistan, a state thrice as large in area and five

Address at the University of California, San Diego, California, March 1964, on the invitation of Prof. Roger Revelle, Leader of President John Kennedy's team for the study of Salinity and Water-logging in West Pakistan.

times as populous as California, consists in its essentials of the flat Indus plain in the West and the fertile delta of the Ganges in the East. In terrain, in climate and in some of its problems of hydrology the Western part of Pakistan resembles California closely. I shall therefore take most of my illustrations from Western Pakistan though the bulk of what I shall say applies equally to the whole country.

When I said a moment back, that *modern* Pakistan came into being in the last century, I used the word *modern* advisedly. For the history of Pakistan in fact goes back some 4,000 years. This was the land which nurtured the civilization of Mohenjodaro, a civilization contemporaneous, if not earlier than that of Egypt and Babylon. This was the land that the Vedas of the Indo-Aryans celebrated three thousand years ago. And this was the land whose rich cities drew Alexander the great a millennium later. Alexander's soldiers in all their triumphant career, had never crossed a river mightier than the Indus, a river with twice the annual flow of the Nile.

The Indus and each of its five tributaries flowed through a green ribbon of farm land a few miles wide. In between these green ribbons of cultivation lay broad stretches of parched desert. But farming the fertile regions, there lived tribes of virile men in cities protected by ramparts of burnt bricks. By the time the Greeks had forded the fifth river, the resistance these cities offered had broken their spirit. Alexander decided to venture no farther eastwards.

The history of invasion of Pakistan and the fierce resistance offered was repeated over and over again in succeeding centuries; it was repeated with the Arabs, it was repeated with the Afghans, and it was repeated with the Turkish Mughals. Each invader brought his skills and culture, not the least the Afghans who brought the country the gift of Islam, seven hundred years ago, turning its face decisively westwards towards Makkah.

This was the country to which the British came as conquerors in 1857.

The British changed the face of the land. Not content with ribbons-like patches of cultivation which they found along the five rivers, some far-sighted men in the Indian Civil Service decided to harness the technology of their day to create a garden out of desert and the scrub. They built low dams across the five rivers, on foundations of sand and gravel – a structure which had rarely been attempted elsewhere and whose essential stability remains to most hydraulic engineers a miracle to this day. "Behind these dams, they diverted the waters into great new canals. These canals have a total length of ten thousand miles; some of the biggest are as large as the Colorado River. The canals were carefully designed as to width, depth and slope in such a way, that the silty water moves just fast enough, so that it neither erodes the beds of the canals, nor chokes them by depositing sediment"¹ to get this even flow was no mean task in surveying

¹ Revelle Report, *The Problem of Salinity and Water-logging in West Pakistan* (1962).

and engineering, for let us not forget that the nearly flat Indus plain slopes no more than a foot per mile.

With the canal system was created a fine railway network, and perhaps the finest road system east of Suez. West Pakistan multiplied in prosperity, in fertility and in population. It was in this sense that modern Pakistan was the creation of the nineteenth century technology.

But even after such a heavy initial dose of technology, Pakistan failed to become in the subsequent decades a technologically advanced country. Something went grievously wrong. The first flush of prosperity lasted no more than a few decades. The country was built upon just one resource – agriculture. However, agricultural production did not keep in step with the natural population increase. And even on the purely technical side, soon after its inception, the very miracle of the canal network began slowly to stifle the fertility it was meant to create, by spreading the blight of water-logging and salinity in areas wherever a canal passed.

The reasons for this failure of technology are not far to seek. The technology which created Pakistan did not touch us more than skin deep. It was a graft that never took, it was not something which became an integral part of our lives. And all for one basic reason: The only way to communicate the garnered wisdom and knowledge of one generation of men to another is by precept and education. It sounds hard to believe, but in Pakistan no provision whatsoever was made for scientific or technical or vocational education.

Thus, even though the entire object of bringing the canal waters was to increase agricultural production, no one dreamt of introducing agricultural technology as part of the educational system. On the level of advanced education, whereas something like thirty-one liberal arts colleges were built, one in each district headquarter, to teach British history, to teach the metaphysics of Aristotle, to teach laws of equity and principles of jurisprudence, the whole of East Pakistan had to be content with one agricultural and just one engineering college. This for a population then approaching fifty million people. The same story repeated itself at all middle levels of technicians. The result could have been foreseen. The level of agricultural practice remained as static as under the Mughals. The chemical revolution of fertilizers and pesticides touched us not. The manufacturing crafts went into complete oblivion. Even a steel plough had to be imported from England. I just cannot convey to you my own personal sense of disbelief when some years ago I was told that here in the United States, every state University grows around the nucleus of a land grant college – every other faculty being added later. So contrary this seemed to me to anything I had ever been used to!

Why did the British administration fail to place any emphasis on technical education, mechanical skills, and agricultural husbandry? For mechanical skills

there is perhaps a simple explanation. In the economic organization of the empire, Britain was to be the only manufacturing unit. All its other parts like the American colonies, like India, like Nigeria, like Sudan were designed as units to supply raw materials. Thus, from a British administrator's point of view, there was no need to foster mechanical or industrial skills for they would never be exercised. But by the same token this attitude is harder to understand so far as agriculture is concerned, the attitude which, for example, failed to build up proper Agricultural Advisory and Extension Service.

Perhaps, there is a simpler and a more charitable explanation possible. The educational system of British India was essentially the creation of one man – the great historian Lord Macaulay. Writing his recommendations in 1835, he strove to give us the best that Britain could then offer. This best unfortunately did not embrace science and technology. In so far as Britain's industrial revolution had been brought about by gifted amateurs, there was in the Britain of the nineteenth century no appreciation of the role of technical education in fostering industrial growth. The first British Royal commission on technical education did not report till 1884. The first parliamentary grant for scientific and technical education amounted to no more than 3,000 dollars. The first polytechnics did not come till 1890. Unlike Germany, unlike modern Russia, unlike I believe the United States, Britain did not build up an industrial society through the medium of education. Whether Britain suffered at all in the long run, I shall not say. But for us, the whole educational system was patterned on that of the British. This was disaster.

In 1947, after nearly ninety years of foreign rule the nation started on a new phase in its life. For us in Pakistan, the struggle for independence had been fought on two fronts: first against the British for independence, and second, for a recognition of our separate existence.

In 1947, on the debit side, we started with a desperately poor population, with per capita income of fifteen cents a day. We started with no manufacturing capacity or skills and we started with a primitive agriculture, with one-fifth of our cultivated areas bedeviled by the twin curses of salinity and water-logging.

On the credit side, however, we had two assets. Firstly, the revolution of rising expectations had hit Pakistan as strongly as it had hit the rest of the underdeveloped world. Second, although there was no clear notion on how to affect an economic transformation of the society, there was no resistance to newer ideas or to a newer organization of life. Like every nation smarting under recent defeat of arms, we too had passed through the phase when everything Western was an anathema. But in 1947, this phase of our history was a long way behind us.

We spent the first ten years of our independent existence in trying to redress, almost feverishly, and perhaps with some disregard of sound economics or personal suffering for the consumer, the imbalance in industrialization. The basic

consumer industries like textile, sugar, cement, and paper manufacture were hastily created by private enterprise. But it may perhaps be more right to date the era of our purposeful growth from 1958. This was the year President Ayub Khan came into power. This was the year that a state Planning Commission started to function with the fullest vigor. Around then, we began receiving the maximum help from our friends and allies, not the least from the United States. And since then we have saved and invested yearly some 20% of the national income.

For the last three years, the economy has grown at the rate of 6% – the highest in Asia. Industrially we have reached the maturity of being able to project a modest heavy industrial complex based mainly on the one industrial resource we seem to have in plenty – natural gas. A ship-building yard and two refineries have been built. Two steel plants with a total capacity of about half a million tons are rising fast. Four technical universities are functioning and a network of polytechnics is projected. In agriculture we are on the threshold of the Green Revolution. One of the most imaginative of recent scientific missions was the 1961 team of university scientists, hydrologists, agriculturists, and engineers, assembled on President Kennedy's behest by Jerry Wiesner, and led by Roger Revelle to study the salinity and water-logging problem in West Pakistan. The team has made some far reaching recommendations. Looking far beyond their original assignment, the team with characteristic vision has produced a blueprint for raising our agricultural productivity. The implementation of these recommendations will change the entire look of our agricultural economy, and currently the nation is gearing up for this.

But perhaps I have given you too rosy a picture – a picture of a progressive society on the path to a certain economic breakthrough. When I speak of the 6% rise in national income, please do not forget the starting level of fifteen cents per day per person, nor the suppressed hunger of just one meal a day which most of us can get. When I speak of projected industrial complexes and steel, please do not conjure the picture of rising competition for Pittsburgh as the US Congress was once abjured to do. The whole of Pakistan consumes no more than 60 MW of power. Do not in any case underestimate our lack of expertise and experience. We are very liable to make exactly the same mistakes the British made. It is possible that a new phase of industrialization may come, this time financed by loans from the World Bank and helped by experts from abroad, but that this phase may leave the heart of the country so far as development of indigenous technical talent is concerned, as untouched as ever before. And there is real danger that this could happen, for the World Bank or any other aid-giving agency, with the best will in the world, is interested more in the completion of a project in the shortest possible time rather than in seeing that it should have been executed by the Pakistani technicians to give them the requisite confidence and experience.

There are other dangers too – the nightmare, for example, of the discontinuance of foreign aid programs. I wonder sometimes if the Clay Committee Report could ever have been written if more people among the richer nations of the world were really aware of the intensity of world poverty. Even apart from the moral aspects of world development, I wonder if it is to all known that we too are in our very humble way financing some of the prosperity of richer nations. Year after year I have seen the cotton crop from my village in Pakistan fetch less and less in the world market. Year after year I have seen the imported fertilizer cost more and more. To Pakistan alone, this widening gap of industrial and commodity prices has cost three-quarter of a billion dollars in the last seven years. In Paul Hoffmann's phrase the under-developed world has been paying a subsidy perhaps greater than all the sums received in aid. I wonder sometime how a US negotiator can ever have the heart to beat us down a few pennies on the price of a bale of jute, when these pennies can mean so very much in Dhaka and so little in New York.

But to return to the stresses, we are likely to meet, during the processes of our growth, I have often heard it asserted in the West and I quote from Arnold Toynbee that "if one abandons one's traditional technology and adopts a foreign technology, the effect will gradually work its way down till the whole of one's traditional culture is undermined." The same remark has been made more powerfully by Francis Dart in a recent issue of the *Foreign Affairs* quarterly. In his words: "Technology is not science. Tools and skills are found everywhere but science is a unique development limited almost entirely to the western world.

A true scientific revolution which could support technology would profoundly affect the cultures of the underdeveloped nations in their deepest traditions. ... It would be certain to bring about major changes in religious philosophy, ethics and social structure."

Personally, I do not accept this thesis. For one thing, when one considers the flowering of modern science in a spectrum of countries which includes not only the Western world, but also the Soviet Union, one wonders if we yet correctly know the precise condition under which science is likely to flourish. For another, the practical experience of Japan hardly seems to support this view. And if early Islamic society is any guide, and let us not forget that for five hundred years of early middle ages, this society was the greatest conscious patron and best exporters of sciences, it is unlikely that what Toynbee and Dart predict will come to pass for Pakistan. Certainly there are no signs of it today.

Our chief stresses are likely to be purely economic. We face in this respect a dilemma peculiar to most developing countries: in a growing polity there is nothing more destructive of morale than economic inequality. In a country where general affluence prevails, large differences of income can perhaps be tolerated, but not so if the bulk of your population is at a starvation level. But at the same time, the very facts of under-development contain the seed within it of unlimited

economic opportunity. Ours is a closed protected market. A permit to set up a fertilizer plant is a certain passport to a million rupees. Pakistan today resembles the American Frontier of a hundred years ago, with the shootings and the risks taken out. Our dilemma is, how does one combine opportunity and disproportionate inequalities it must produce from affecting general morale? Perhaps your rich experience may suggest an answer.

Let me conclude by briefly reiterating some of the things I have said. Our nation today is fired with the objective of eradicating poverty. First and foremost we have to acquire the requisite skills to accomplish this. It is here that the knowledge and idealism of a technical community like yours in California can help. Science and technology are the greatest instruments of change in the modern world. Also, among the scientific communities lie some of the greatest reserves of humanistic idealism. For me it is a sign of hope that the scientist is increasingly beginning to realize his responsibility for world development.

Nine hundred years ago, the great physician of Islam, Al-Asuli, writing in distant Bokhara, divided his pharmacopoeia into two parts, *Diseases of the Rich* and *Diseases of the Poor*. If Al-Asuli were alive today and could write about the afflictions of mankind, I am sure he would again plan to divide his pharmacopoeia into the same two parts. Half his treatise would speak of the one affliction of Rich Humanity – the psychosis of nuclear annihilation, the other half would be concerned with the one affliction of Poor Humanity, their hunger. In diagnosis he might perhaps add that the two afflictions spring from a common cause – the excess of science in one case and the lack of it in the other. I wish and hope in his prognosis he would not have to add that it is the faltering will of the scientist-physician which needs building up much more than that of the patient.■

6

Mathematics in Science – A Poetic Language

The ideas put forward by Salam here are vivid. But more than the specific ideas, we are interested here in his description of science itself. For him, science is the attempt to find in the complexity of nature something which is simple and beautiful. This is quite different from the usual view that science collects facts and uses them to make machines and gadgets. Salam sees science as a truly imaginative activity, with a poetic language of its own. This is an arresting point that Salam made: that the mathematics in science is a poetic language, because it spontaneously throws up new images, new ideas.

– Jacob Bronowski, *Insights*, p. 106.

I am a theoretical physicist, and we theoretical physicists are engaged on the following problem. We would like to understand the entire complexity of inanimate matter in terms of as few fundamental concepts as possible. This is not a new quest. It is the quest, which humanity has had from the beginning of time – the Greeks were engaged on it. They conceived of all matter as being made up of fire, water, earth and air. The Arabs had their ideas about it too. Scientists have been worried about this all through the centuries. The nearest man came to solving this problem was in 1931 when, through the work done in the Cavendish Laboratory in Cambridge, we believed that all matter consisted of just two particles – electrons and protons – and all forces of nature were essentially of two kinds, the gravitational force and the electrical force.

Now, we know that this view of 1931 was erroneous. Since that time the number of particles has increased to thirty, and the number of elementary forces to four. In addition to the electrical and gravitational forces, we now believe that there are two other types of force, both nuclear – one extremely strong, and the other extremely weak. And the task we are engaged on is to try to reduce this seeming complexity to something, which is simple and elementary.

Now, the type of magic, which we use in order to solve our problem is first to rely on the language which we use throwing up ideas of its own. The language, which we use in our subject is the language of mathematics, and the best example of the language throwing up ideas is the work of Dirac in 1928. He

started with the idea that he would like to combine the theory of relativity and the theory of quantum mechanics. He proceeded to do this by writing a mathematical equation, which he solved. And to his astonishment, and to everyone's astonishment, it was found that this equation described not only the particles – electrons and protons – which Dirac had designed the equation for, but also particles of so-called anti-matter, anti-electrons, anti-protons.

So, in one stroke Dirac had increased the number of particles to twice the number. There are the particles of matter and there are the particles of anti-matter. In a sense, of course, this produces simplicity too, because when I speak of thirty particles, really fifteen of them are particles and fifteen of them are anti-particles. The power of mathematics as a language that suggests and leads you on to something, which we in theoretical physics are very familiar with, reminds me of the association of ideas which follows when possibly a great poet is composing poetry. He has a certain rhyme, and the rhyme itself suggests the next idea, and so on. That is one type of way in which invention comes about.

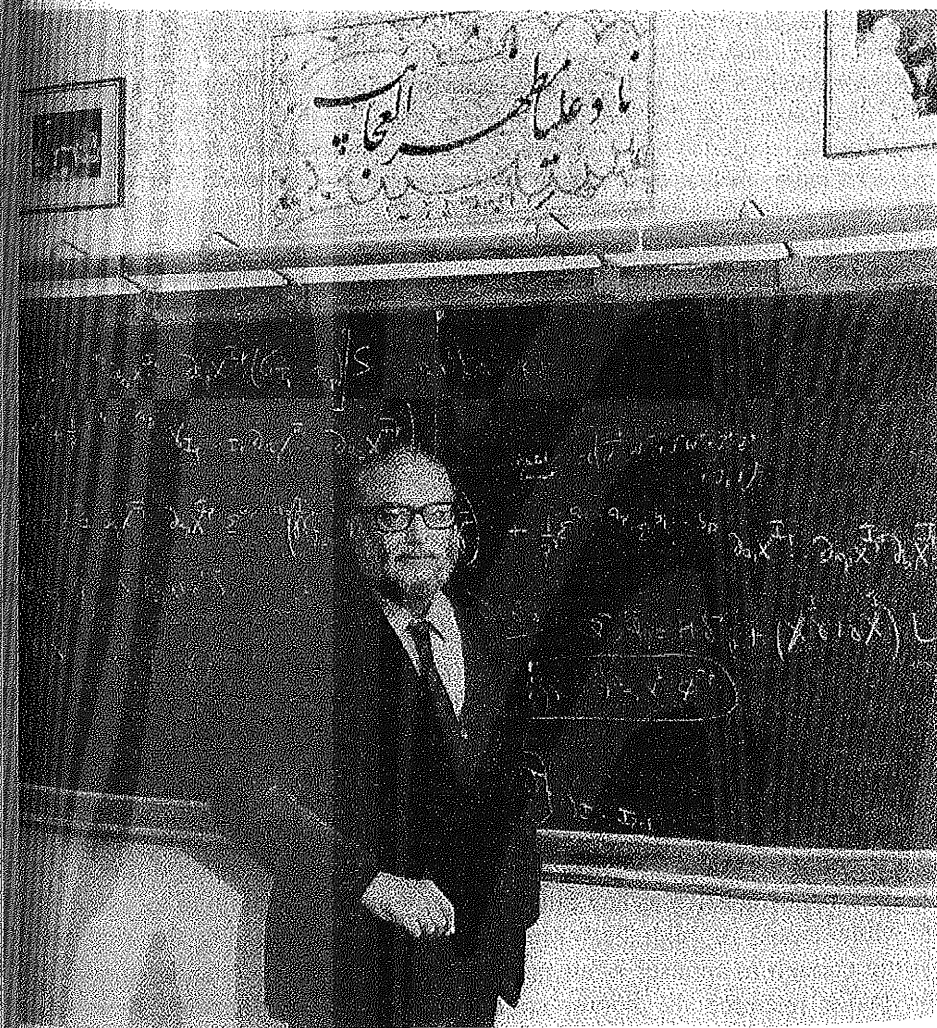
The second type of idea, which we use to solve our problems is the idea of making a physical picture. A very good illustration is the work of the Japanese physicist Yukawa in 1935. Yukawa started to ponder on the problem of the attractive force between two protons, and he started with the following picture. Suppose there are two cricketers, who have a cricket ball, and they decide to exchange the ball. One throws the ball and the other catches it, perhaps. Suppose they want to go on exchanging the ball, to and fro, between them. Then the fact that they must go on exchanging the ball means that they must keep within a certain distance of each other.

The result is the following picture. If one proton emits something which is captured by the second one, and the second one emits something which is captured by the first one, then the fact that they have to capture, emit, re-absorb constantly, means that they will remain within a certain distance of each other. And someone who cannot see this intermediate object, this ball, the object we call the meson, will think that these two protons have an attractive force between them. This was Yukawa's way of explaining the attractive force between two elementary particles.

The result of Yukawa's work was that he predicted that there do exist such particles which play the role of intermediate objects. And he predicted that such particles would have a mass about three hundred times that of electrons. Yukawa made this prediction in 1935. In 1938 these particles were discovered, and we now firmly believe that the forces of nature, all forces of nature, are transmitted by this type of exchange of intermediary particles.

Now, so far, I have been talking about our methods, but what is really important are our aims. Our aim in all this is to reduce the complexity of the

thirty elementary particles and the four fundamental forces into something, which is simple and beautiful. And to do this what we shall most certainly need is a break from the type of ideas, which I have expressed – a complete break from the past, and a new and audacious idea of the type which Einstein had at the beginning of this century. An idea of this type comes perhaps once in a century, but that is the sort of thing which will be needed before this complexity is reduced to something simple. ■



27. Abdus Salam at ICTP

7

The Less-Developed World: How Can We Be Optimists?

"Between the frontiers of the three super-states Eurasia, Oceania, and Eastasia and not permanently in possession of any of them, there lies a rough quadrilateral with its corners at Tangier, Brazzaville, Darwin, and Hong Kong. These territories contain a bottomless reserve of cheap labor. Whichever power controls equatorial Africa, or the Middle East or Southern India or the Indonesian Archipelago, disposes also of the bodies of hundreds of millions of ill-paid and hardworking coolies, expended by their conquerors like so much coal or oil in the race to turn out more armaments, to capture more territory, to control more labor, to turn out more armaments, to capture more territory, to control. ..."

Thus wrote George Orwell in his only reference to the less-developed world.

I wish I could disagree with him. Orwell may have erred in not anticipating the withering of direct colonial controls within the 'quadrilateral' he speaks about; he may not quite have gauged the vehemence of urges to political self-assertion. Nor, dare I hope, was he right in the somber picture of conscious and heartless exploitation he has painted. But he did not err in predicting persisting poverty and hunger and overcrowding in 1984 among the less privileged nations.

I would like to live to regret my words but twenty years from now, I am positive, the less-developed world will be as hungry, as relatively underdeveloped, and as desperately poor, as today. And this, despite the fact that we know the world has enough resources – technical, scientific, and material – to eliminate poverty, disease, and early death, for the whole human race.

The visible portents of 1984 are there for all to see. Notwithstanding every physical and ideological exhortation, the agricultural production of all but the richest countries is static. It would seem that the industry of food production is as investment-intensive as any other. We are only just beginning to speak, in not too mute tones, of high birth-rates. There are none among the rich nations willing enough to sponsor a fair price structure for the commodity market – the one major resource the poorer countries possess for financing their meager

Reprinted from *The World in 1984* (Vol. 1), edited by Nigel Calder, pp. 16-17. London: Penguin Books, 1964.

development plans. There are likely to be higher and still higher tariff walls against their cheap manufacturers. And every year the battle to keep the trickle of foreign aid programs flowing becomes fiercer and fiercer. The United Nations Development Decade from all indications is likely to end with a whimper.

But this is not what makes me so utterly pessimistic. Never in the history of mankind has a change happened all at once. The one great change of the first half of this century – the passing of the Colonial Age – was the culmination of fifty years of crusading. In most places it all started with a few men, whose passionate fury first overwhelmed their own people and then succeeded in rousing the liberal conscience of their captors, bringing home to them also the utter economic futility of holding down an unwilling people. This is the normal process of change. What makes me worried is that no such thing has yet happened in the underdeveloped world so far as the harder crusade against poverty is concerned. And in the few places where realization has come, it has not been purposeful enough yet to bring down the internal, social and the organizational barriers, nor to be able to defy external pressures. In the next twenty years I trust this crusade will come to be preached with the fury it deserves within the poorer countries. I can only hope it remains inward-turning – that it does not become a destructive wave of antagonism against those fortunate few among the nations of the world who somehow inherited most of this earth's resources and do not quite need them all.

But this will take time. For 1984 itself, I am resigned to Orwell's grim picture, with want and misery unchecked – unless, of course, there rises earlier somewhere a new Messiah, the one who can preach that in this age when technological miracles are indeed possible, the raising of living standards everywhere to a decent human level is first and foremost a moral problem, and a collective world responsibility. ■

8

Iqbal Memorial Lectures: Symmetry Concepts in Modern Physics

Prefatory Remarks

During March 1965, I was privileged to deliver the First Iqbal Memorial Lectures at the invitation of Radio Pakistan. This is a reprint of the lectures where I took as my theme Symmetry Concepts in Modern Physics.

Iqbal was our greatest poet, our deepest thinker. I take pride in the association of his name with these lectures for two reasons. Firstly, as a true philosopher Iqbal fully recognized that there is no finality in philosophical thinking and that the progress of all philosophical thought must depend on new discoveries in the field of science. Again and again in his lectures on *The Reconstruction of Religious thought in Islam* (Lahore, 1930), he points towards the possibility of breakthroughs still to come in the field of physics which may give a new outlook to philosophy. This, indeed, is just what has happened since Iqbal's death twenty-seven years ago, and an account of these newer concepts will be the theme of my lectures. Even though Iqbal did not live to see the fulfillment of his own prediction, I am glad that Radio Pakistan has decided to dedicate these lectures to his memory which lives for ever.

My second reason for welcoming Iqbal's association with these lectures is this: I believe that the rise of a great poet or a great writer or a great humanist in any civilization is not an isolated incident – that it is always accompanied by an equally significant emergence of men as great in sciences and philosophy. To give one example, it is good to recall that at the last zenith of Islamic civilization, in the early part of the eleventh century, the *Shahnama* of Ferdausi preceded the encyclopaedic *Qanun* of Ibn Sina and the equally encyclopaedic *Tanjim* of Al-Biruni by no more than twenty years. I am absolutely certain that Iqbal's greatness in poetry and philosophy will not go unmatched so far as the present Muslim renaissance in science is concerned. I believe that, now that the nation has begun once again to aspire to higher things, the age of Iqbal, just like the age of Ferdausi eight hundred years ago, will produce in Pakistan its great scientists who will rival the brilliance of Ferdausi's contemporaries like Ibn Sina and Al-Biruni.

Abdus Salam's Symmetry Concepts in Modern Physics: Iqbal Memorial Lectures, ed. by Fayyazuddin and M.A. Rashid. Lahore: Atomic Energy Centre, 1966, 55 pages, with Figures and Tables. [The Figures and Tables, not in Salam lectures, have been deleted for this volume.]

These lectures are an account of man's search for unity in the understanding of the physical universe and the ultimate nature of matter. During these lectures I would like to show how rewarding the faith in the eventual unity, the eventual harmony, the eventual beauty of the basic laws of nature has proved in unraveling some of the deeper insights we have achieved. Some of these concepts are extremely deep. I can only hope I have not relapsed into a misty profundity which is quite often in science a cloak for one's own ignorance.

First Lecture

From the dawn of all civilization man has wondered and asked questions – questions about the color of the sunset, about the brilliance of the stars, about rainfall and cloud-burst, about the trajectory of a bullet and a space satellite, and eventually, about life itself. But in all this questioning there has occurred one recurring theme. Man has always believed that the answers to these questions, when they come must follow from just a very few general principles. Man has always held to an unreasoning faith in an eventual unity, an eventual simplicity, an eventual symmetry in any basic laws which may govern the Universe. The history of science is the history of a search for such all embracing, such unifying concepts. Within the compass of inanimate matter we shall discuss what we believe today to be the ultimate constituents of all matter, and what we think are the fundamental principles which govern its behavior.

Perhaps the first people in the history of mankind who made a systematic search for a unified and a rational explanation of the universe were the Greeks. The Greeks sought the ultimate principles governing nature to lie in four elements of which they believed all matter was made. These, in their view, were the elements of air, water, fire and earth. Greek thought permeated also early Islamic thinking and this classification of elements remained as the basis of medieval science. The real quantitative breakthrough, however, came in the nineteenth century as a result of thousands of painstaking and accurate laboratory experiments accompanied by the deepest analytical thinking. The nineteenth century chemist could show that in the last analysis all matter in the Universe, living or dead, and of whatever form – absolutely everything – was made up of just 92 different types of elements, and that every element could be subdivided into tiny units – the so-called atoms. These are the atoms of hydrogen, helium, lithium and beryllium, and so on. The science of chemistry is more or less summarized in the so-called periodic table of atoms; this is a chart, invented first by the Russian chemist Mandeleev, which orders the atoms in the manner we have described: hydrogen, helium, lithium, the table ending with the ninety-second entry uranium. The nineteenth century chemist believed that the atoms were indivisible, immutable entities, that they could not be divided any further. One found that the atoms attracted one another when they were a short distance apart; this was the chemical force responsible for building from atoms

the complex forms in which matter manifests itself. One also found that one could not push atoms too close together; they repelled each other on being squeezed too closely. This repulsion – this resistance to squeezing clearly meant that atoms could be pictured as objects with a definite size – as little hard balls. To get an idea of atomic sizes one may remember this. If a cricket ball is magnified to the size of the earth, then each atom in it will look as large as the original ball itself.

The discovery that absolutely everything is made up of 92 types of atoms was something tremendous. The discovery made the nineteenth century scientists absolutely dizzy with excitement. The atoms were the “elementary particles”; the chemical force was the “elementary force”. In 1891, Lord Kelvin, addressing the British Association for Advancement of Science, went so far as to say, “We have discovered in physical sciences all that can be discovered. The rest is more and more refined measurement.” But by one of those curious accidents that seem so frequent in the history of science, this same year was destined to bring in a new revolution in physics. This was the year that J. J. Thomson, in the Cavendish Laboratory at Cambridge, first demonstrated that atoms were after all not indivisible – that all atoms could be split into still smaller units. After some thirty years of feverish experimentation at Cambridge by two of the greatest men of this century, Sir J.J. Thomson and Lord Rutherford, there emerged a synthesis still deeper than any the chemist had proposed. One could now show that all atoms – all 92 of them – were divisible; that they were made of just three fundamental units. These fundamental units are very tiny chunks of matter, each weighing less than 10^{-27} grams. These three fundamental units are called protons, neutrons and electrons. All atoms have a central nucleus, made up of protons and neutrons. Around this central core whirl a number of electrons, just like planets orbiting around the sun. An atom of hydrogen contains one electron, of helium two electrons, of lithium three electrons right up to uranium, the ninety-second atom in Mendeleev's table where the central nucleus is surrounded by exactly 92 electrons. The secret of Mendeleev's table, its order, lay in the number of electrons contained in any given atom. To summarize, all atoms consist of a central core, the so-called nucleus. All nuclei contain about equal numbers of protons and neutrons. Surrounding the nuclei are clouds of electrons whirling around at fantastic speeds – speeds reaching hundreds of thousand miles a second. In the heart of every atom there ever continues a dance of the electrons together to make molecules and stack molecules to form crystals and living cells was also nothing but a manifestation of the basic electrical forces of attraction and repulsion. The deeper that one went the more it became clear that the electrical force was the key to the understanding of structure of matter. For example, one can now understand why metals differ from semi-conducting transistors. Some metals – copper and silver for example – have the property that electrons contained in their atoms are somewhat loosely bound; these electrons can drift freely and course throughout the crystal lattice of copper or silver. Not

so for a transistor; there the electrons are not so loosely bound; they cannot flow as easily; the transistor is only semi-conducting. In biology one understood, for example, that our bodies resemble a modern electrified city. In a human body, just as in a modern city, there is a vast electrical network of nerve fibres connected centrally to the brain. It is the electrical impulses which the brain sends out that control physiological processes. For example, a muscle contracts when an electrical impulse shoots out charged molecules – the ions of acetylcholine – at its end. Physiology, biology, chemistry – all science in principle – could be understood in terms of the electrons and the protons and the one fundamental – electrical force – between them. No wonder in 1928 the great physicist Dirac – successor of Newton in the Lucasian Chair of Mathematics at Cambridge – could say with justifiable élan, “With protons and electrons we can explain the whole of chemistry and most of physics”.

Dirac was obviously right about chemistry; was he also right about chemistry; was he also right about “most of physics”? In 1928, it seemed likely that he was. For earlier, Faraday and Maxwell had made another remarkable discovery. An electron or a proton when accelerated could emit electrical waves just as a stick moving up and down in a pool of water sets up water waves in the pool, so an accelerating electrical charge could set up electromagnetic waves in space. And Maxwell and Faraday discovered that these waves could be picked up by other electrons in a receiving set, just as the waves in a water pool set up by the moving stick would make a cork floating in the pool bob up and down in rhythm with the moving stick. An example of the waves Maxwell and Faraday spoke about are the radio waves on which voice is transmitted; the electrons in the cathode ray tubes or transistors of receiving set move in harmony with the electrons in the transmitter. If the wave length of the radio waves is shortened an accelerating electron or a proton would set up what we call infra-red radiation. The human frame is not attuned to receive radio-waves but we – or rather our skins are excellent receivers for the shorter infra-red wave length; we call such waves “heat radiation”. The sun is continuously beaming out infra-red radiation; we receive them in exactly the same manner as a radio set receives the radio signals. Still shorter electrical waves can be received by the nerve cells of the retina of our eyes. We call these waves “light radiation” – ordinary visible light. Still shorter waves are X-rays, still shorter waves are called gamma-rays. The crucial point is all phenomena of radio waves of heat and light and X-rays are basically the same. All these are electrical radiations, produced when electrons or protons in a transmitter oscillate. The waves are received by other electrons and protons in the receivers' radio tubes, in its transistors, in the retinal membranes, in the sensitive nerve cells of the human skin or by electrons and protons contained in the silver atoms of a sensitive photographic plate. God said, Let there be light; to make light, and to perceive it, He made protons and electrons – the two fundamental particles of physics.

Second Lecture

In the first lecture we gave the picture of physical sciences which obtained in 1930. With just three fundamental particles, electrons, protons and neutrons, and just one type of force – the electrical force – one seemed to have synthesized most science. There were, however, yawning gaps in our knowledge. The nuclear core of every atom contains about equal numbers of protons and neutrons. A neutron is a chunk of matter as heavy as a proton but with no electrical charge, and therefore no electrical attraction or repulsion. What is the neutron's role in the scheme of things? What holds a nucleus together?

Since 1930, physics, and since 1945, most of humanity, has been occupied with the nuclear problem. The world of the nucleus revealed a new – a completely unexpected – richness. Since 1930, one has discovered that though all known stable forms of matter we had encountered so far in nature consisted of just the three fundamental particles mentioned before, there do exist other companion particles – companions to the protons, to the neutrons, and to the electrons – as fundamental, as elementary, as these three. It is the story of these newer entities and the domain of phenomena they have revealed that will be our major concern henceforth.

We have called these newer particles companions to the known ones. It is important to realize that the new particles were not discovered by the classical procedure of sub-division of protons, neutrons or electrons. The principle of divisibility which took us from ordinary bulk matter to atoms and then from atoms to protons, does not seem to function any more. With protons, electrons and the newer particles one seems to have reached the limits of divisibility. We do not know if this is because we have not tried hard enough. We believe we have; it may well be that we have reached a level of something completely new in human experience. If I liken these particles to a brick thrown against a wall, it would seem not that the brick fragments into still smaller pieces, for the first time it appears as if we are receiving back five or six whole bricks, identically alike to the first that was thrown. If one has indeed reached the end of the line of divisibility then one is at a level of comprehension quite different from any that has ever gone before.

But before we describe these particles, their inter-relations and interactions and the concepts associated with them we would like to review some of the basic concepts of modern physics, concepts which we shall need to refer to again and again.

The first concepts we shall need are the classical ones of momentum and energy. Momentum is the amount of motion possessed by an object when it is moving. In mathematical language it is simply the product of the velocity times the mass of the body. Similar to the concept of momentum is another concept – perhaps still more crucial for my lectures – the concept of spin, or angular momentum. If an object is rotating around an axis, a spinning top or a spinning

cricket ball, for example, we say it possesses angular momentum. The faster an object rotates, the larger is the angular momentum carried by it. Now there is a very important law of classical physics which states that the amount of momentum or angular momentum remains constant unless there are external forces tending to stop the motion or the spin. A spinning fly-wheel will go on spinning if there is no friction of its bearings. A bullet fired from a gun or an arrow shot into space will go on moving in a straight line if there was no air friction to stop their motion, or gravitational force to pull them down. Perhaps this great law of classical physics is completely obvious to you in this satellite age. But it certainly was not obvious to Aristotle nor to Ibn-Sina. For it seemed contrary to all common experience of mankind. If we roll a ball on a table, one's normal experience is that sooner or later it will come to a standstill. One might assume – and this is in fact what Aristotle did – that the natural tendency of a moving object is to stop; that some force is needed to keep things in motion. It took the genius of Galileo and Newton to contradict Aristotle. They asserted that just the contrary is the case. If there is a natural tendency for a moving object it is to persist in its motion. One should not look for an agency which keeps it moving, one should rather look for an agency which is likely to stop it. What a revolution in thought this bold assertion of Newton and Galileo brought about! This intrinsic attribute of persistence of motion is called "inertia" – plain laziness if you like. The tendency to persist in moving in a straight line is called conservation of momentum; the persistence to spin is called conservation of angular momentum.

These conservation laws have been tested millions of times under controlled conditions. When we say controlled conditions all we mean is that one has attempted to eliminate extraneous forces like friction very scrupulously. These laws represent an ultimate truth, the distillation of our physical experience. But is there something deep we can infer from these, or do we have to accept them as obstinate facts which must be incorporated in any description of nature we make? It happens that for the conservation laws of momentum and angular momentum one can relate these to something deeper, something more profound, something more basic. By a process of mathematical reasoning which we cannot go into, Dirac and the great Hungarian Physicist Wigner, were able to show that the tendency to persist in straight line motion – conservation of momentum – can be inferred as a basic law of nature provided we assume that the results of any physical experiment are independent of where the experiment is performed. Not many of us have ever stopped to ask ourselves the question: Do a proton and an electron on the planet Mars attract each other with the same force as they do on the planet Earth? Once the question is formulated most of us would instinctively say, yes; why should the force not be the same? It would be an intolerable complication in the scheme of nature if laws of physics depended on one's location in the Universe. But what is the proof? Dirac and Wigner assert that if we can verify – with arbitrary precision – that momentum is conserved, we can

be sure that the basic laws of physics are the same all over the Universe. Likewise if spin is conserved, we can be sure that space is rotation-invariant, that the results of an experiment – like the pitch of a whistle, or the rate of our respiration, will not depend on whether we face East or West, here or on Mars. I have lived for about sixteen years with this reasoning of Wigner and Dirac, a reasoning which connects things so distinct, so disparate; which connects symmetry of the Universe with conservation of spin; a reasoning at once so abstract and yet so concrete. I still marvel at its boldness, its audacity and its sweep. It is one of the most powerful things I know of.

So much for classical physics. The second discipline we shall make frequent reference to is Einstein's theory of relativity. There are few subjects in Physics which have aroused such strong misconceptions. The reason is not difficult to find. Relativity theory makes statements about time, within a context used by the physicist. Since immemorial days however, the professional philosopher has always felt that "time" was a concept which was his exclusive preserve. The misconceptions arose when the philosopher started to interpret Einstein's work in his own mysterious language. To most philosophers, the theory has been obvious, compelling, and a priori – after its discovery. To me there is nothing a priori about relativity. Relativity is based on a remarkable, on a far reaching experiment, whose result one would never have conjectured at before it was performed. The experiment is this: if we take a candle and measure the velocity of light which it emits we get a certain value. More precisely we discover the velocity is one hundred and eighty six thousand miles per second. Now move the candle as fast as you possibly can. Naively one might imagine that the light velocity – determined by the time it takes for light to get to us – should depend on whether the candle is moving or not. Not so, however, when the experiment was actually performed by Michelson and Morley. The velocity of light is exactly the same irrespective of whether the source of light moves towards or away from us with whatever speed. Not only that; it is also unchanged irrespective of what we may be doing: we may try running away from the candle with a speed even as fast as that of light itself. A normal sane person might expect that in that case the light would never reach us. But astonishingly enough, one would be wrong again. Light will still reach us with the same velocity as before. Astounding, unexpected! As we said, there was nothing a priori about the Michelson-Morley experiment nor its result. The results of the experiment just had to be incorporated into physics. Einstein's profound analysis accomplished just that. Einstein expressed his analysis in some most spectacular language – that the resolution of the apparent paradox lay in the relative character of time. Einstein's language was a translation, an expression of certain mathematical relations. We cannot here try to go deeper into this; for our purposes the crucial content of relativity is the following. From the constancy of velocity of light Einstein deduced that matter and energy must be identical. To illustrate, Einstein asserted, for example, that a lamp-shade which absorbs the energy of light waves

must get heavier, the absorbed light energy manifesting itself as increase in its matter content. The radio transmitters of Radio Pakistan, pouring electrical energy into space, are progressively diminishing in their matter content. Luckily these transmitters are replenished; they receive energy also from the electrical main but one might worry about the sun, for the sun is certainly getting lighter every day; it is losing mass which is continually converting to energy of heat and light. These statements can be, and have been, verified hundreds of times in the laboratory.

So much for Relativity Theory. The third set of concepts we shall have occasion to refer to are the concepts of quantum theory. Quantum theory, like relativity, began in the early part of this century with certain experiments whose results one would never have believed possible, so obstinately contrary are they to anything we had apprehended before.

Quantum theory asserts that there are in nature certain fundamental units and that a number of physical quantities can exist only as integer multiples of these basic units. One simple example is quantization of electric charge. A proton is some 2,000 times as heavy as an electron. But both carry the same quantity of electric charge. All charges in nature exist as integer multiples of this one fundamental unit. Take another example. I have spoken before of spin, of angular momentum. Recall that this is the amount of rotation possessed by a given object. One would never have believed that one cannot impart an arbitrary amount of spin, for example, to a cricket ball. Yet this is precisely what quantum theory asserts. It is impossible to find in nature a spinning object – a top, a cricket ball – whose spin is not half-integer multiple of a basic unit discovered by Planck. Tops can rotate with spin value equaling half of a Planck unit or one Planck unit, or two units, or two and a half units – but never, never, with 1.3 or 2.7 or 20.67 times Planck's basic value. For quantum theory integers, or at worst half-integers, are sacred, inviolate. Quite clearly if the theory did not have the sanction of precise experiments one would never have believed it.

Take one more example: would one believe that the energy carried by a radio-wave or a light ray or heat radiation can exist only in multiples of a certain basic unit in discrete chunks; that energy is quantized? Again, if we did not know that this was true by repeated experimentation one would hardly credit this. In the case of electrical radiation, we designate this basic unit a photon. A beam of light or a beam of X-rays in this quantum view then consists of nothing but a stream of photons, all photons traveling with the velocity of light. The quantum statement is that there is no such thing as a quarter of a photon. The statement that an oscillating electron emits electro-magnetic radiation in the quantum language reads: an electron or a proton emits or absorbs photons when it accelerates and oscillates.

Let us recapitulate. On the basis of what we know, we believe that the Universe, the space-time we live in, is endowed with certain characteristics. We understand the origin of some of these characteristics. Others we are forced to

accept as empirical facts and leave for our successors in the twenty-first and perhaps later centuries to find the deeper basis of. We know empirically that there are certain conservation laws – like conservation of momentum, of energy, of angular momentum. We believe we can find a deeper significance for these laws in the sense that we can correlate them with the properties of space and time. From conservation of momentum one may infer that space is location-symmetric. From conservation of energy we may infer that the results of an experiment do not differ with the epochs of time at which the experiment is performed, that an electron and proton will have the same attractive force today as they had yesterday and will have tomorrow. From conservation of spin, of rotation, we infer that space is rotation-symmetric.

From relativity experiments we know that velocity of light has astonishing properties, that it is invariant, unchanging, irrespective of the motion of the light source, and any motion of the observer. Accept this as something which we must incorporate in our description of fundamental physics, we may then infer that all energy possesses inertia and vice-versa. Experiment has forced us also to accept quantum theory. We know, for example, that we can never impart spin to an object which is not an integer or a half integer multiple of Planck's basic unit. We know that the energy of electromagnetic radiation can exist only in discrete quantum units – the so-called photons. We find this utterly bewildering, utterly astonishing. Why some physical quantities are quantized may be connected with the topological structure of space and time but we do not know. This again is perhaps a problem for the fortunate few of a hundred years after. All we can do at present is to incorporate these facts within the formalism we use. This we have learnt to do.

Third Lecture

By 1930, the physicist believed that all matter in the Universe was composed of three particles – electrons, protons and neutrons. He also believed that all energy, whether it existed as heat or light, was basically electrical in character and that it manifested itself in discrete chunks, in discrete quanta – the so-called photons. All matter and all energy in his view was then composed of just four fundamental entities – *photons, electrons, protons* and *neutrons*. The electrons and protons carry an electrical charge; when accelerating, these particles emit heat or light in the form of photons. The neutron is electrically neutral.

Now these four particles are not just simple chunks of matter or energy. One other property they all seem to possess is that of intrinsic spin. An electron or a proton continually spins like a top around an axis fixed in the body. And as we discussed in the second lecture, this spin motion, like all spin motions in the Universe is a half-integer multiple of the fundamental unit of Planck.

Why should elementary particles behave like spinning tops? What gives them their intrinsic spins? Why should the spin-values be just what they are? The answer to this last question was brilliantly given in 1928 by Dirac at Cambridge

in a paper which is an epic of modern physics. Let us recall the laws of persistence – of persistence of inertia, of persistence of spin. One could show that this persistence was related to rotation symmetry of the Universe. Now Dirac demonstrated that when one married together this notion of rotation symmetry of the Universe, with the ideas of Einstein's relativity, one could demonstrate that electrons or protons must spin – and with the precise values found by experiment.

Dirac's work is one of the monuments of modern physical theory. Not only did Dirac give a deeper meaning to the concept of intrinsic spin, he was also able to deduce from the same equation something even more important. He could show on general grounds that all particles in nature must exist in pairs; that to every particle there must correspond an anti-particle of precisely the same mass, the same spin but of opposite electrical charge. Thus the existence of the positively-charged proton must imply the possible existence of an anti-proton carrying a negative electric charge; if the hydrogen atom exists, there can equally exist an atom of anti-hydrogen, perhaps in some distant corner of the Universe.

Dirac could show that if a particle and an anti-particle collide, both must disappear, their energy, their momentum, their spin going into photons, into heat or light in other words, and this is all that is left of the collision.

In Dirac's language anti-matter is "minus-matter"; matter and anti-matter just cannot co-exist in the same part of the Universe without the ever-impending catastrophe of annihilation; and indeed some astronomers do believe that just this type of annihilation of galaxies and anti-galaxies is taking place at the sites of some powerful X-ray sources in the heavens.

Dirac made his prediction of the existence of anti-matter in 1934; the anti-electron was discovered in cosmic rays the same year; the discovery of the anti-proton had to wait longer till the completion of the giant proton accelerating machine at Berkeley, California in the 1950s. In one stroke Dirac had doubled the number of elementary particles from four to eight. There is an apocryphal story in Cambridge of how Dirac first conceived of the idea of anti-matter, of minus-matter as one may call it. As a graduate student Dirac once attended a 'Problems' Drive – so the story goes – organized by the Cambridge Undergraduate Mathematical Society, the Archimedeans. One of the problems presented was the following. On a stormy night three fishermen go fishing and make a big haul. The storm forces them to seek refuge on a lonely island where they tie up their boats and go to sleep. During the night one of the fishermen gets up; he would like to get away. Without waking up his friends he divides the catch into three equal parts. He finds one fish outstanding. This extra fish he throws into the sea. Taking his one-third portion of the catch he rows away. A short while later the second fisherman wakes up. He does not know that one of his friends is gone already. He too proceeds to divide the haul into three equal parts, finds one fish outstanding, throws it into the sea, and rows away with his one-third. The same thing happens a third time. The problem is, what is the

minimum number of fish – the minimum size of the catch – which can thus be sub-divided three times successively with one fish outstanding each time? The story goes that Dirac thought for a few seconds and then jotted down his answer – minus two. You see, if you divide minus two fish into three equal heaps, each heap will consist of minus one fish, with plus one fish outstanding – minus three plus one equals minus two ($-2 = -1 -1 -1 +1$). Throw the outstanding plus one fish into the sea, take your minus one fish away; plus one and minus one equal zero, so that you are leaving behind on the island precisely minus two fish again, ready for exactly the same sub-division as before. Dirac of course, did not then worry what a catch of minus fish may signify. Nor does the story relate if he got the undergraduate Prize that night. But when faced with minus electrons two years later as a consequence of his relativistic equation, he just had to find a meaning for these anti-objects. Thus, goes the story, was the brilliant notion of anti-particles born and with it the uncovering of one more profound symmetry of the Universe we live in – the symmetry of matter and anti-matter.

Before we go further let us recapitulate once again. In the 1930s view of nature all matter and all energy could be considered made up from four elementary particles or their antiparticles; eight entities in all. Further, every particle possesses a specified value of spin. Now so far we have mainly concentrated our attention to protons and electrons, both these particles carry an electrical charge. We have neglected the “neutron” – a particle as massive as the proton, without, however, its electrical charge. The neutron was discovered in 1930 at the Cavendish Laboratory at Cambridge. Immediately after its discovery the question arose: if the neutron is electrically neutral one could not expect it to attract the charged protons. We had, however, earlier learnt that neutrons and protons together make up the central core the central nuclei of all atoms. What is the force that keeps the nucleus bound together if it is not the electrical force? Why do protons and neutrons inside the nucleus not fly apart? The dilemma appears deeper still when one reflects that even the lightest nucleus is incomparably more compact, more tightly bound than any atom we know of. To compare sizes, if a hydrogen atom is blown up to the size of the city of Karachi, the hydrogen nucleus would be no larger than the Quaid-i-Azam's mausoleum. This compactness, this tight binding must come from some force inside the nucleus – we may call it the nuclear force – and this force must be at least a thousand times stronger than the electrical force which keeps an atom together. The neutron may not carry an electrical charge but it must carry a nuclear charge, and so indeed must the proton since protons too exist within the nucleus.

The tremendous strength of the nuclear force explains why a nuclear bomb – size for size – must be a million times more potent than a chemical bomb; why nuclear fuel in a nuclear reactor must deliver a million times more power than chemical fuel. One had always puzzled about the tremendous output of energy from the stars. With the knowledge of the nuclear force, and nuclear reactions, one knew at long last what makes the stars shine; and how the sun can pour such

vast amounts of energy. The hydrogen in the sun is continually converted by nuclear fusion to helium; star-dust if you like is nothing but high-grade nuclear fuel. I always fondly recall the story of Professor Hans Bethe the night when he first realized that this outpouring of luminous energy from the stars was basically the energy of nuclear reactions – the continual nuclear conversion of hydrogen to helium. Bethe and his wife were standing gazing on the Californian desert sky when Mrs. Bethe said: "How beautifully do the stars shine tonight." Professor Bethe turned slowly towards her: "Would you believe it," he said, "but right now I am the only human being in the Universe who knows what makes them shine at all."

We have spoken of the nuclear force qualitatively so far. Since 1935, the major problem in physics has been to find its quantitative aspects. It is these aspects which shall engage us now. First two lectures are wholly concerned with the electrical force – the force which keeps atoms together; which binds an electron to a proton. One had known from the work of Planck and Einstein that photons – the particles of heat and light – are the quanta of the electrical force. The first question which one asked regarding nuclear force was: what are its quanta?

The first man to ponder on these questions was the great Japanese physicist, Yukawa. Yukawa's thinking, in 1935, went something like this. An electron or a proton when accelerated emits or absorbs photons. One can understand the attractive electrical force between a proton and an electron in terms of an exchange of photons. Think of two rugger players who make passes to each other. One throws the ball over, the other catches it; then throws it back and so on. The passes, the exchange of the rugger ball is impossible to continue unless the players remain within a specified distance of each other, unless they move in consonance. A spectator who watches them from a great distance and who perhaps cannot see the ball will notice only one thing; there are these two men, always close to each other. If the spectator is a physicist used to expressing all physical phenomena as resulting from forces, he will say, there is an attractive force between these men. Take the analogy of the two players over to an electron and a proton. The photon is the rugger ball; the proton emits the photon, the electron absorbs it; re-emits it a short while after, passing it back to the proton. This continual exchange of the rugger ball, the photon, forces the proton and the electron to remain forever in consonance, to move together. The photon is the carrier of the electrical force.

In 1935, Yukawa knew this classical theory of the electrical force. In 1935, the nuclear force, however, was still very much of a mystery. Yukawa asked himself the question: what is the corresponding quantum, the rugger ball, the carrier of the nuclear force? What do protons and neutrons exchange?

Yukawa relates that he used to keep near his bedside a notebook; during the nights he would scribble his speculations in the dark. Every morning he would

eagerly look at what he jotted down in the sleeping-wakefulness of the night before. One morning he discovered he had solved the problem of what the carrier of the nuclear force must be. Yukawa had speculated that there must exist three new elementary particles, one charged positively, one negatively and the third neutral, with masses intermediate between those of the proton and the electron which must play the role of the nuclear rubber balls, continually exchanged between protons and neutrons. Yukawa called these hypothetical particles the mesons. The triumph of this speculation made in 1935 came full twelve years later. In 1947, Powell at Bristol discovered precisely these three particles. Their signatures were inscribed as tracks on a photographic plate when the plate was exposed to a shower of cosmic rays. In the next lecture we shall speak more of these mesons and the nuclear force.

Fourth Lecture

In this lecture we return to the theme of symmetries – in particular the symmetries of the nuclear force. We ended the last lecture with the two nuclear particles, protons and neutrons, each of which carries a nuclear charge. We also mentioned Yukawa's prediction that if the nuclear force exists, there must also exist three particles, three carriers of this force – the so-called mesons. And we ended by speaking of the experimental discovery among cosmic rays of just the three particles – the three mesons Yukawa had speculated about. This was 1947. With the discovery of the mesons, the number of elementary particles had increased to a total of seven. One felt somehow that enough was enough; one felt one had all the ingredients to make complete theories of the two basic forces of nature – the electrical force as well as the nuclear force. Unfortunately, when one actually tried to consider the theories quantitatively, even though one succeeded admirably with the electrical force, one met with miserable failure in the case of the nuclear force. And this in spite of the fact that in the meanwhile the physicist had learnt to unlock the force itself in all manner of nuclear devices. Clearly something was still missing. Just the total of seven elementary particles was not enough.

Now, this something missing started coming in from 1947 onwards – first in small measure among the cosmic ray showers, then in torrents from the newly-constructed proton-synchrotrons from Brookhaven, Berkeley, Dubna and Geneva. Between 1947 and 1962 something like thirty new particles were discovered, each seemingly as elementary, each seemingly as fundamental as the proton and the meson. The techniques used to isolate these particles experimentally form a saga of modern experimental physics. We shall not discuss these experimental methods but the theoretical concepts one had to develop to understand their correlations, their interactions – the concepts to comprehend the very reasons for their existence, shall form the theme of this lecture. The ideas, the concepts, are not easy; they are still in a stage of development and flux.

Briefly the experiments showed this. As discussed before, the nuclear particles, the protons and neutrons, are spin $\frac{1}{2}$ particles. Between 1947 and 1954 one discovered a total of six new spin $\frac{1}{2}$ particles all closely resembling protons and neutrons. There was, in nature, then a multiplet of eight nuclear objects, all with spin $\frac{1}{2}$, all as basic to the nuclear force, as a familiar neutron or the proton. Likewise, the number of Yukawa mesons increased, once again from three to eight. There were, in Yukawa's language, not just three but eight carriers of nuclear force. And as if this was not bad enough, in addition to these two families of mesons and nucleons two other families of particles were discovered, each family consisting of nine particles. These large numbers of particles – 34 in all – were bewildering. Even more bewildering appeared in the 1950s their mutual interactions. As a rule all nuclear particles can emit or absorb mesons – but the question arose: which ones? What was the basic law governing the behavior of these new objects? The situation was confused for a number of years but then around 1960 a definite pattern began to emerge. And the pattern was the following. What we have called the nuclear charge, consists really of two distinct varieties. These varieties have been named as isotopic charge (I_3) and hyper-charge (Y). The names of the charges are not important. All that is important is that nuclear charge exists in two forms. What one discovered was that in a multiplet of eight particles, some will carry hyper-charge, others will carry isotopic charge, some others will carry both. The type of meson a nuclear particle emits or absorbs depends on the type of charge it carries. Together with electric charge, the two nuclear charges make a total of three. One could then classify all newly-discovered particles in terms of just what charge each one could carry.

Let us summarize at this stage once again. A new era opened up in physics during the years 1947-1960. As a result of feverish experimentation with the giant accelerators, a new and perhaps somewhat embarrassing richness was discovered among the set of nuclear particles and among mesons. It is not important to remember the names of the particles or their different correlations; all that is necessary is to remember that there were in early 1964 a total of eight particles constituting a nuclear multiplet of spin $\frac{1}{2}$, nine other nuclear particles constituting a multiplet of spin $\frac{3}{2}$; eight Yukawa mesons forming a multiplet of spin 0, and another nine mesons of spin 1. Notice the recurrences of the magic numbers – eight and nine. The particles in a multiplet could be distinguished by giving either their electric charge or hyper-charge or isotopic charge. These facts which we have summarized took years of patient experimentation, long and lonely vigils among the snows of Jung-fraujoch, or involved working with capricious multi-million volt accelerators. These results were not arrived at in a day, they had to be deduced painstakingly from data which was often inadequate, and almost always cluttered with inconsequential secondary details. Professor P. T. Matthews at Imperial College, London, once gave a brilliant description of how hampered the experimental physicist in our subject is. The only tool an

experimental worker has is a beam of protons accelerated by a synchrotron or in a cosmic ray burst. One directs this beam on to a lump of copper or aluminum. From the number and variety of particles which fly off at a given angle to the original beam direction, one is required to reconstruct and deduce the spins and the charges and the types of forces which exist among the fundamental particles. The analogy which Matthews gave was that of a beautiful marble statue in a darkened room, on which one is spraying a jet of water from a hose. One cannot see the statue but one can collect the amounts of water splashed from each square inch of the statue. Suppose you were set the task of reconstructing how the statue itself looks – the lines and the figure and the shape and the only information supplied was this splashing spray, I am sure you would begin to sympathize with the modern experimental physicist.

Returning to our multiplets of eights and nines, the very first question which arose was this: Here are eight or nine objects all essentially similar; can we in some approximation treat these particles as manifestations of one single entity? Is there some unity in this multiplicity? Is there some single symmetry principle in terms of which one may comprehend the complexity presented by the particles? We earlier had an example of this essential unit, in the particles and anti-particles of Dirac. One can speak of a particle and its anti-particle – a proton and an anti-proton – as a two-fold multiplet. But we also know that the two are intimately related; the proton is the minus particle of the anti-proton. The two are the facets of the same reality, two opposite sides of the same coin. There is a unity in the multiplicity. Or to put it another way, Dirac's postulate of particle anti-particle symmetry in the Universe makes it possible conceptually to speak of particles alone. One need never speak of the two-fold multiplet. One need never speak of the anti-particles. It is the symmetry principle which is of paramount importance, the existence of a two-fold multiplet (particle and anti-particle) is something which follows as a consequence. Take another example. You may recall when I spoke about spin. I said a spin $\frac{1}{2}$ particle can exist in two states. It can either spin in a clock wise direction relative to its direction of motion, or in an anti-clockwise direction. One could think of spin $\frac{1}{2}$ protons as two distinct particles, one spinning clock-wise, the other spinning anti-clock wise, one behaving like a left screw, the other behaving like a right screw. A completely equivalent description would be to say, there is just one entity, the spinning proton, but there is additionally a symmetry principle which permits one to infer from the existence of left-spinning proton the existence also of a right-spinning one. Take one more example. If one has a Persian carpet or an embroidered bed cover, with a pattern on it, one can describe the pattern in many different ways. Take as an example a hexagonal pattern, six flowers arranged as a hexagon. To someone wishing to weave a similar carpet one may either give the positions of all the six flowers individually or simply describe just one typical flower and ask him to make a hexagon of like flowers. To describe what a hexagon is one would say, rotate the first flower through 60 degrees. The symmetry principle then is

the rotation of 60 degrees. The symmetry principle provides the unifying principle for the six-fold multiplet. The pattern itself is a manifestation of the symmetry. The problem in nuclear physics then was, what is the symmetry principle underlying its three charges and its multiplets of the eights and the nines? What is the secret of the carpet pattern of the Universe?

Now, about one hundred years ago, one of the greatest mathematicians of the world, Sophus Lie, had tabulated all conceivable abstract symmetries. He had classified all symmetries, or symmetry groups, as he called them, in terms of the number of key directions. Recall that to make a hexagon there was just one key direction – the 60 degree rotation. Recall that for particle anti-particle symmetry there was just one key direction: change plus with minus. Recall that for spin $\frac{1}{2}$ there was just one key direction, flip over a left screw with a right screw; a right spin with a left spin. To realize this physically you can look in a mirror. A mirror reflects a left hand to a right hand. The problem Sophus Lie solved was this: given the number and type of the key directions, he could then say unambiguously how many flowers – how many particles – the pattern, the multiplet, could contain. For the case of the carpet pattern, even a child can work out the answer. Given the key element, the key direction I mentioned before, rotate through 60 degrees – one must get six flowers all lying on the corners of a hexagon. Suppose, however, the key directions are more complicated; suppose there are in fact three directions three symmetries, like flipping electric charge with hyper-charge and hyper-charge with isotopic charge. How shall one work out the detailed pattern? Sophus Lie gave the following method. Consider a triangle – an equilateral triangle – with corners representing the three types of charges, and now attempt to make all conceivable patterns by a juxtaposition of such triangles in a specified manner. What are the patterns one arrives at? One of the first one gets is a hexagon again, but with two extra elements at the center, making a total of eight corners; of eight elements, of eight particles if you like. The numbers 8 and 3 are interrelated. From the symmetry of the three charges, of electric, isotopic and hyper, one may infer that multiplets of nuclear particles – the manifestations of this symmetry – must exist in multiplets of eight and this is precisely what one had experimentally discovered.

Lie's theory is in fact one of the profoundest, one of the most beautiful mathematical constructs. Sophus Lie was the Michelangelo of classical mathematics. Even though we may have failed to convey its depth, we do hope the basic idea itself is clear, which let us repeat again.

In the quest for symmetry of nuclear law, one had found a deep correlation between the number of charges, electric, hyper and isotopic and the numbers of elementary particles in a nuclear multiplet. The multiplets themselves are scarcely important after the symmetry is discovered. However, the fact that the eight particles in a multiplet have the same nuclear properties implies that the three charges themselves are similar, are mutually interchangeable; the three charges are but a manifestation of one single charge or they are the different

aspects of a single entity. Technically the symmetry is known as the $SU(3)$ symmetry-three for the three types of charges we started from, "U" for Unitary.

The Unitary symmetry appeared in early 1964 to be the symmetry of nuclear physics. This was encouraging – tantalizing. But there seemed one serious difficulty. On the basis of $SU(3)$ one could understand multiplets – patterns – consisting of eight particles. What about the patterns – consisting of nine particles which had been found experimentally? In Lie's mathematical classification one could easily check that the only possible patterns of spin $1/2$ or spin $3/2$ which could at all exist must consist of either 8, or 10, or 27 particles – but never of nine. Recall that in early 1964 one knew of only nine nuclear particles of spin $3/2$. If Lie's ideas were right, there must exist a tenth particle, otherwise the whole edifice would collapse. Those of you who may be familiar with the philosophy of Pythagoras may recall the famous emblem which Pythagoreans displayed in their secret meetings. This was a figure made from equilateral triangles with exactly ten corners. In Lie's language this was one of the allowed $SU(3)$ patterns. In 1964, one knew of nine spin $3/2$ nuclear particles, filling all the corners of the Pythagorean figure except the apex. The crucial tenth was missing. The characteristics of this particle – named Omega minus – could almost exactly be predicted from the existence of the remaining nine. One could assert that the particle must carry an electric charge of -1 unit, a hypercharge of -2 units and no isotopic charge. One could predict its mass – it must be nearly twice as heavy as a proton; its spin must of course be $3/2$. The search was on and in February 1964 this elusive object was finally discovered. A team consisting of 32 experimental physicists at the Brookhaven National Laboratory in the United States finally tracked two Omega minus's among literally the millions of other particles that were scanned. These precious two are in fact just the only two Omega minus's in the Universe that we know of. Their discovery completely vindicated the $SU(3)$ Unitary symmetry. The possibility that such a symmetry might exist was first conjectured by Japanese physicists, led by Professor Sakata, in 1959. It was elaborated in the present form in 1961 by one of my pupils in London, Y. Ne'eman, and independently by Professor M. Gell-Mann at the California Institute of Technology. The $SU(3)$ symmetry scheme represented a deep synthesis in nuclear physics. The validity of the symmetry was established in February 1964. The same year, however, $SU(3)$ was no longer new. A deeper still synthesis came in September 1964 and a still, still deeper one in January 1965. From its somewhat measured growth the physics of elementary particles has acquired in the last six months a hectic, a breath-taking pace. We shall deal with these very, very recent developments in the next lecture.

Fifth Lecture

In this last lecture we wish to discuss two things. First, we wish to discuss the most recent synthesis achieved in respect of the symmetries of the nuclear force. Second, we would like to speak of two other forces of nature – the

gravitational force and the so-called weak force. With this our survey of all known forces of nature will be complete. We shall finally make some remarks about the general outlook in the subject.

We ended the last lecture by mentioning the $SU(3)$ symmetry group as the basic underlying symmetry of the nuclear force. Recall that the symmetry takes its name from three types of charges, electric, hyper and isotopic. The symmetry lies in treating all these three charges as if they were manifestations of just one unitary characteristic. It is perhaps good to remind once again – when we use the words “manifestation of a single unitary characteristic”, we do not wish to load the phrase with philosophical or mystical connotations. The word “manifestation” is used in the precise mathematical sense of Sophus Lie. Let us never forget that mathematics is the language of physics. We further said that using Sophus Lie's ideas had the further corollary that nucleons and mesons must be found in nature in multiplets of 8 or 10 or 27. And this seems confirmed by experiment.

Now throughout these lectures we have noticed that the elementary particles and elementary phenomena have been characterized by two types of properties. First are the so-called internal properties, like electric charge or hypercharge; second are the external properties like spin. Spin is called external because it has its deeper roots in the structure of something external to all of us – in the structure of space and time. It had always been a recurrent dream in physics that some day one may be able to find a deeper unification between these two types of properties, that internal and external properties might merge in one single whole. This would be the ultimate synthesis, and it is the story of this synthesis achieved in the last few months that we wish to describe during the first part of this lecture.

Before we go on to discuss the new symmetry itself, let us briefly go over the concept of spin once again. In terms of Sophus Lie's ideas, intrinsic spin symmetry may be called the $SU(2)$ symmetry. This is because, as we learnt in the fourth lecture, a spin $1/2$ particle can be pictured as an object rotating either clockwise or anticlockwise relative to its direction of motion; in terms of multiplets, these two left and right spinning objects form a two-fold multiplet. In Sophus Lie's language, just as three varieties of charge give rise to an $SU(3)$ symmetry, two varieties of spin give rise to $SU(2)$. Just as $SU(3)$ multiplets consist of 8, 10 or 27 particles one can show that higher spin multiplets can contain 2 or 3 or 4 different spinning objects. To take a concrete example – in nature we have 8 particles of spin $1/2$ and 10 of spin $3/2$. In making these counts we made no distinction of left spin from right spin. If we do make this distinction the multiplets really consist of $8 \times 2 = 16$ and $10 \times 4 = 40$ distinguishable entities making up a total of 56.

Now as a first part of the program to marry, to synthesize, spin with charge, let us assume that the right and left spins can be treated on a basis completely analogous to the three types of charges. This is to say, consider a total of six

types of charges, electric charges spinning clockwise, electric charges spinning anti-clockwise; hyper-charges spinning clockwise, hypercharges spinning anti-clockwise, and so on. These six charges will give rise to a new Lie group, the group $SU(6)$. Now the mathematics – the group theory – of the $SU(6)$ structure has its own volition. One can either look up Lie's works or work out oneself diagrammatically the structure of the $SU(6)$ multiplets. The first result one discovers to one's astonishment is that the lowest nucleon multiplet of $SU(6)$ must contain precisely 56 quantities. We said "astonishment" because 56 is just the number of distinguishable nucleons which we know exist in nature. This 56-fold multiplet of $SU(6)$ now contains both the familiar protons and neutrons (of spin $1/2$ as well as the exotic Omega minus (with spin $3/2$) of which just two specimens are known in the Universe. A still deeper nucleons' synthesis has been achieved; spin $1/2$ and spin $3/2$ are no longer distinct; 56 of them form one single entity; spin is nothing but a new form of charge; one has married internal symmetries of charge with the external symmetries of space and time.

The basic idea of marrying spin with charge was first conjectured essentially twenty-seven years ago by the great Hungarian physicist Wigner. In its present form it was worked out in September 1964 by Professor Feza Gursey – the great Turkish physicist, by Professor L. Radicati from Italy and by Professor B. Sakita – a young physicist from Japan.

Now the $SU(6)$ symmetry was profound, but it was not profound enough. It had one serious flaw. When speaking of space-time, and of its marriage, of its synthesis with charge, one must make sure that the space-time concepts one uses accord with the relativity theory. The situation with spin in 1964 was the same as the one Dirac faced in 1928. At that time one knew of spin, but it seemed to have no relevance to relativity. Dirac had the audacity to put relativity first. He did not consciously look for spin; a synthesis of relativity with quantum theory led him automatically to the concept of intrinsic spin. What we wanted was a similar miracle to happen for the case of the nuclear particles. One would like to marry relativity into the structure of the three charges, electric, hyper and isotopic. One wanted for the proton the analogue of Dirac's equation for the electron. And this was precisely what was done in January of this year. One found it was necessary to generalize $SU(2)$ once again to $SU(4)$. Combining this with the $SU(3)$ the final symmetry turns out to be $SU(12)$ – the largest yet in respect of the symmetries of nuclear force. The multiplets extend once again, from 56 to 364 particles; what is much more important, one has at long last the beginning of the dynamics of nuclear physics. One can perhaps now write down a quantitative measure of the nuclear force, the dream of Yukawa in 1935, the problem which has eluded physics for the last thirty years. A fair part of this work was done by Pakistani physicists notably at the International Centre of Theoretical Physics at Trieste. Some of the names concerned in the development are those of Mirza Baqi Beg, Dr. M. A. Rashid, Dr. Riazuddin and Dr. Fayyazuddin.

This concludes what we wanted to say about nuclear force. Let us take stock of the situation and make a survey of fundamental physics. We have so far discussed two forces, the electric and the nuclear. These give us a complete comprehension of the world of the atom and the world of the nucleus. There are in addition, however, to these two forces two more. One is the ever-present classical force of gravitation – the first Universal force to be discovered; the force which holds us all captive to the surface of the earth. Every particle in nature carries what one may call a gravitational charge. The astonishing thing about gravitational charge is that, unlike all other charges, there is only one type of gravitational charge. There are no positives or negatives among them. Put it another way; every particle in nature attracts every other particle – there is no gravitational force of repulsion. A second remarkable fact about gravitation is its extreme weakness. Relative to the electrical force the gravitational force is a billion, billion, billion times weaker. To give you an idea of the orders of magnitude involved, let us take a comparison. The gravitational force produced on the surface of the earth is the result of all the matter contained within the earth itself. An ordinary electro-magnet used for lifting material, about a centimeter or so in length, however, can produce an electro-magnetic force as strong as earth's gravitation – the small electromagnet can counteract gravity. Size for size a tiny electrical system is as potent as the pull of the whole earth. But if the gravitational force is so weak, why is it so persistent while the electrical force is not? We are all made up of electrons and protons, we are electrical systems, but none of us exerts an electrical force on anyone else even though the electrical forces are so very much more powerful. The reason is the one we have already mentioned; electrical charge is of two types – positive and negative – while the gravitational charge is of only one sign. The electric force cancels itself out, the gravitational force never does. Another question which arises with the gravitational force is: are there carriers of gravitational force just like the carriers of the electric and the nuclear forces? Theoretically, there should be. Experimentally, unfortunately, we do not know. Because of the tenuous weakness of the gravitational force, it would be very hard to detect these carriers the so-called “gravitons”. This surely is one of the things which perhaps 21st century physicists will have more to worry about.

In addition to gravity, there is one more force of nature – the so-called weak force. It is something very peculiar; its very existence was unknown until the neutron was discovered in 1930. It is a force which seems to have just one purpose: to make all elementary particles decay. Whereas a free proton or a free electron left to itself lives on for ever, this is not the case for a free neutron. Left to itself a free neutron disappears in about ten minutes; it decays into a proton, an electron and a new and rather mysterious particle called the neutrino. It was as if the neutron was really a time-bomb; its fuse-rate being determined by the so-called weak force. The neutrino, the signature of this weak force, is a particle of spin $1/2$, it carries no charge, and it travels with the velocity of light. And it

has one more extraordinary peculiarity. Whereas left-spinning neutrinos exist, there are no right-spinning neutrinos. The neutrino does not obey the mirror symmetry principle. Like Hoffmann in Offenbach's opera, a neutrino reflected in a mirror sees no shadow of itself. Why this is so, we do not know.

Summarizing once again, we have four forces: the strongest is the nuclear. The next in order of strength is electrical, 100 times weaker than the nuclear force. The next is the weak force, a million times weaker, and the still next the gravitational force, which is a billion, billion, billion times weaker still. All particles can be considered manifestations of these forces. The nuclear force seems to obey the SU(12) symmetry law. The multiplets consist of 364 or more particles; the photon is the signature of the electric force. The electric and the nuclear forces seem to be fairly well understood, and so is the gravitational force, since the days of Newton and Einstein. The weak force is completely mysterious. Still more mysterious, however, is the fact of why all these forces are divided in this somewhat arbitrary manner; why do they possess such different symmetry properties? Why do their strengths vary so very much? Physics can never rest till this final synthesis comes; the synthesis which, for example, must include not only electric and the nuclear charges, but also the gravitational. We have certainly not solved the whole of physics. In Oppenheimer's phrase: "The future will be only more radical and not less, only more radical and not more familiar, and it will have its own new insights for the inquiring mind." The same thought was expressed in an eloquent line by Faiz Ahmad Faiz:

*Kai baar iski khaatir zarre zarre ka jigar cheera
Magar yeh chashm-e-hayraaṅ jiski hayraani nahiṅ jaati*
(Moved by the mystery it evokes, many a time

I have dissected the heart of the smallest particle,
But the eye of wonder, its wonder-sense is never assuaged!)

If there is one hallmark of true science, if there is one perception that scientific knowledge heightens, it is this spirit of *tahayyur* (wonder). The deeper that one goes, the more profound one's insight, the more is one's sense of wonder increased.

If we have done anything, we hope to have shown that allied with the wonder of God's creation, all explanation we have ever found is based on symmetry concepts. Whenever faced with two rival theories for the same set of phenomena one has always found that a theory more aesthetically satisfying is also the correct one. The Holy Book in Sura Al-Mulk (*Al-Qur'an*, Chapter 67) has proclaimed the faith of the true scientist: "Thou seest not in the creation of the All-merciful any imperfection. Return they gaze; seest thou any fissure? Then return the gaze again, and again, and thy gaze comes back to thee dazzled, aweary." ¶

9

A New Centre for Physics

The idea of creating, under the aegis of the United Nations, an international center for theoretical physics took shape five years ago. Some three years of hard persuasion at the forum of the International Atomic Energy Agency (IAEA) in Vienna were needed to get it accepted and a further year was required to prepare for its inception in October 1964. The Centre has now completed its first academic year and it is time, perhaps, to assess how far the ideals, which went into its creation have actually been realized.

The International Centre for Theoretical Physics was conceived with two distinct ideals in view. First, as a contribution to international collaboration in science; second, as a contribution to physics in developing countries, particularly through the help it might give to the work of senior physicists there. Theoretical physics happens to be one of those relatively advanced disciplines where decisive advances in recent times have come not only from the physicists from the West and the East, but also those from some of the developing countries – Brazil, China, India, Korea, Lebanon, Pakistan, Turkey, and others. One could hope that a successful theoretical physics institute might possibly set a pattern for a future United Nations University.

The first occasion on which the Centre was discussed was the High Energy Physics Conference in September 1960. In his banquet address John McCone, who was then the Chairman of the U.S. Atomic Energy Commission, mentioned with approval a suggestion that nations collaborate in setting up a joint high-energy accelerator. Some of us – Hans Bethe, Robert Sachs, Nicholas Kemmer – who assembled afterward wondered how practical the suggestion might be and if one might not perhaps start on a smaller scale with modest, truly international center for theoretical physics – financed by one of the UN family of organizations.

The same month I had the privilege of being able to voice, on behalf of the Pakistani government, this visionary ideal in the form of a resolution at the annual conference of the IAEA at Vienna. We were fortunate to receive co-sponsorship of the resolution from the governments of Afghanistan, Federal Republic of Germany, Iran, Iraq, Japan, Philippines, Portugal, Thailand, and

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Turkey. As the list of sponsors indicates, the setting up of such a center was of interest not only to the developed countries, but also to some of the less privileged ones. The hope was that a center of this type, besides providing a venue for collaborative research, might also help in resolving one of the frustrating problems which active scientists in poorer countries face – the problem of isolation. Such men could come fairly frequently to the Centre to renew their contacts and engage in active research in fields like nuclear theory, high-energy physics, theory of plasma, and solid state physics.

Right from the beginning we received enthusiastic support from the IAEA's directorate and from the physics community. Niels Bohr, before his death, expressed his wholehearted support; scientific panels convened in 1961 and again in 1963 by the Agency's Director General, S. Eklund, forcefully recommended its creation. (Members of the panels were A. Bohr, P. Budinich, B.T. Feld, L. Infeld, N. Levy, R.E. Marshak, A. Salam, W. Thirring, J. Tiomno, and L. Van Hove.) Unfortunately, there was not the same unanimous response from all atomic energy commissions around the world. At the 1962 annual conference of the IAEA (where these commissions are represented), even though the creation of the center was accepted in principle, the feeling of the IAEA's decision-making organ, the Board of Governors, was that it could not recommend committing IAEA funds toward it without other funds, at least to start with. Additional offers of financial assistance from interested member states were solicited; of the four received (from the government of Italy, for a center to be located in Trieste, from Denmark for Copenhagen, from Pakistan for Lahore, and from Turkey for Ankara), the most generous was the Italian government's offer, with P. Budinich, professor of physics at the University of Trieste, as the moving spirit behind it. This was accepted in June 1963 and the Centre started functioning October 1, 1964 with a charter for four years.

This first year's activity at the Centre covered two disciplines in theoretical physics: physics of elementary particles and plasma physics. The Centre had a staff of fifty-two, made up of twenty-eight nationalities. This included twenty-five postgraduate and postdoctoral fellows, sponsored by the IAEA and UNESCO, most with previous research experience, the majority coming from countries in South America, East Europe, Africa, and Asia. Among the senior physicists who spent one or more terms at the Centre during its first academic year were: A.O. Barut (Turkey, USA), S.M. Berman (USA), M. Fayyazuddin (Pakistan), C. Fronsdal (Norway), J.J. Giambiagi (Argentina), E. İnönü (Turkey), F. Janouch (Czechoslovakia), S. Kamefuchi (Japan), T.W.E. Kibble (UK), H.J. Lipkin (Israel), K. Nishijima (Japan, USA), C.R. Oberman (USA), J. Polkinghorne (UK), I. Saavedra (Chile), H. Stapp (USA), A. Tavkhelidze (USSR), S. Tzitzeica (Rumania), B.M. Udgaonkar (India), J. Werle (Poland) and Y. Yamaguchi (Japan).

In addition to a normal research program, the Centre organized an extended seminar for each of the disciplines covered, particularly organized for those who had lived away from active centers for long periods; on plasma physics in October 1964 lasting four weeks and on high energy physics during May and June 1965. The plasma physics seminar (with twenty-one lecturers and eighty other participants) was co-directed by M.N. Rosenbluth (USA), B.B. Kadomtsev (USSR) and W.D. Thompson (UK). This must be the first occasion when all three major schools of plasma physics – the US, the Soviet, and the European – collaborated in running an extended joint advanced course. The seminar on high-energy physics brought together for eight weeks, thirty-three lecturers and one hundred and twenty other participants from twenty-nine countries. Again we were exceedingly fortunate in that some of the world's most active physicists could come to stay and lecture in Trieste.

It is not for me to speak of the quality of research contributions from the Centre. All I can say is: we were very fortunate. In Weisskopf's eloquent words, the Centre's contributions included some of the decisive achievements of physics during the last year. One can never budget for this; perhaps the men who had lived away from active centers for two or three years were bottling up ideas which they feverishly poured forth and developed at the earliest opportunity that came to them.

At the last meeting of its Scientific Council, Van Hove most generously paid the Centre the following tribute.

"When one sets up an institute, one expects a period of gradual start where people gather, where people begin to select their problems, and where gradually, the time of original contribution to the field develops. We have here seen this whole process in a not only very accelerated but very successful form. Within a span of time of less than an academic year, the Centre at Trieste has succeeded in gathering a considerable number of people, very active in various parts of theoretical physics, and has right away, despite the material difficulties which are encountered in a beginning period, succeeded to cohere them in a manner that a flow of extremely important and extremely original contributions came out and established the scientific reputation of the Centre all over the world in the established places beyond any shadow of a doubt. The contributions have been of such utmost importance that it has become very natural for scientists from all over the world to pass through Trieste when they are traveling, or to come to Trieste whenever some opportunity offers itself.

"One should realize what this means for the Fellows, for the young people who are here. Although the place is very young, just in its period of build-up, most of them had the opportunity to meet leading scientists in the field, to listen to lectures, to discuss points in these lectures, to discuss points in the literature with the best specialists. One can, I think, regard the seminar on elementary particle physics which is going on now as some kind of brilliant culmination of this period of activity. Everything that is important in the field, everybody who makes contributions of some evidence in the field will have passed through Trieste, will have discussed in Trieste,

and for the people who are here as members of the Centre, in particular for the people who come here to get first-hand contact with the field, contact which they cannot get in their own country, I think the opportunities of education and research which have been offered are truly remarkable."

To summarize then, in all humility, we can take pride in that the Centre succeeded during its first academic year in three crucial ways.

1) It encouraged good physics, not in just one field of theoretical physics, but in an interdisciplinary manner. To maintain this interdisciplinary tradition the plans for 1967 include an extended seminar ranging over the entire spectrum of theoretical physics; thus to recognize again its essential unity – something which has not been attempted on this scale for a long time.

2) We could, here, lay foundations of an active, a lasting, and a prolonged cooperation between physicists from the East and West. During 1964-65 a total of eighteen physicists – senior and junior, working for periods from two months to a full year – came to the Centre from East Europe. During 1965-66 the collaboration will take a still sharper form when two groups of plasma physicists, the Soviet and the American (some twenty-five senior men) meet and work together for a full year. This type of collaboration is impossible, at present, to achieve elsewhere.

3) The Centre has helped physicists from developing countries who, after long periods of silence, have begun to write and publish during their visits to Trieste. Specifically for them, the Centre has instituted a new scheme of associateships. The idea is to give selected active men from developing countries the privilege of coming to the Centre for one to four months every year. The Centre pays for their travel and living expenses in Trieste. The times (and indeed the frequency of the visits) are left completely to the associates. So far eight associates have been elected. The plan is to extend the privilege to some forty more leaders of research in developing countries. This may cover nearly all the first-rate men. One may hope that this (financially guaranteed) possibility of remaining in touch (even while they are permanently located in their own countries) might persuade some of the best physicists from less privileged countries not to exile themselves permanently abroad. There is no claim that this is the only way to halve the brain drain, but this is one way and it is worth trying.

As I said earlier, the Centre was created for a period of four years. The decision if it should continue at all – and where – will be taken at the IAEA's Board of Governors meeting next year. In the final analysis then, its continued existence depends on the atomic energy commissions of the IAEA's member states. Basically the problem, as always, is financial. At present nearly two-thirds of the Centre's normal annual budget of \$400,000 comes from just one source – the host government, contributing through the IAEA. The rest comes from the IAEA itself, with a small share from UNESCO. The Centre's present mandate

(and its sources of finance) run out in 1968. We must find new sponsors, within the IAEA, within the atomic energy commissions of the world, and among foundations outside, if the initiative taken in creating this first faculty of a future UN University is to endure.

The Centre is fortunate in having a Scientific Council consisting of Professors S. Vallarta, J.R. Oppenheimer, V. Weisskopf, A. Bohr, V.G. Soloviev, and A. Matveyev. It could never have come into existence or run as it does with no administrative problems but for the warm, consistent, and enthusiastic support of IAEA's Director General, S. Eklund. Two university institutions, the University of Trieste and Imperial College, London have liberally and generously contributed to its success by giving the Centre its staff. The Centre's inception and its organization mark it as a new type of venture – an essay in collaboration between the East and the West, and the poorer nations; an essay in collaboration for pure science organized under the aegis of the United Nations. The idea is the embodiment of the international ideal; it must succeed. ▯

10

The Isolation of the Scientist in Developing Countries

Five hundred years ago around 1470 A.D. – Saif-ud-Din Salman, a young astronomer from Qandhar, working then at the celebrated observatory of Ulugh Beg at Samarqand, wrote an anguished letter to his father. In eloquent words Salman recounted the dilemmas, the heartbreaks of an advanced research scholar in a poor developing country: “Admonish me not, my beloved father, for forsaking you thus in your old age and sojourning here at Samarqand. It’s not that I covet the musk-melons and the grapes and the pomegranates of Samarqand; it’s not the shade of the orchards on the banks of Zar-Afshan that keeps me here. I love my native Qandhar and its tree-lined avenues even more and I pine to return. But forgive me, my exalted father, for my passion for knowledge. In Qandhar there are no scholars, no libraries, no quadrants, no astrolabes. My star-gazing excites nothing but ridicule and scorn. My countrymen care more for the glitter of the sword than for the quill of the scholar. In my own town I am sad, a pathetic misfit. It is true, my respected father, so far from home men do not rise from their seats to pay me homage when I ride into the bazaar. But some day soon all Samarqand will rise in respect when your son will emulate Biruni and Tusi in learning and you too will feel proud.”

Saif-ud-Din Salman never did attain the greatness of his masters, Biruni and Tusi, in astronomy. But this cry from his heart has an aptness for our present times. For Samarqand of 1470 read Berkeley or Cambridge; for quadrants read high-energy accelerators; for Qandhar read Delhi or Lahore and we have the situation of advanced scientific research and its dilemmas in the developing world of today as seen by those who feel in themselves that they could, given the opportunity, make a fundamental contribution to knowledge.

But there is one profound change from 1470. Whereas the emirate of Qandhar did not have a conscious policy for the development of science and technology – it boasted of no ministers for science, it had no councils for scientific research – the present day governments of most developing countries would like to foster, if they could, scientific research, even advanced scientific research. Unfortunately, research is costly. Most countries do not yet feel that it carries a high priority among competing claims for their resources. Not even

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indigenous applied research can command priority over straightforward projects for development. The feeling among administrators – perhaps rightly – is that it is by and large cheaper and perhaps more reliable to buy applied science on the world market. The resultant picture, so far as advanced research is concerned, remains in practice almost as bleak as at Qandhar.

First and foremost among the factors that affect advanced scientific research is the supply of towering individuals, the tribal leaders, around whom great institutes are built. There are perhaps 2-3 percent of all men who are trained for research. What is being done in the under-developed world to ensure their supply? Most developing countries are doing practically nothing. Quite the contrary, with all the obstacles and hazards, which beset a poor society, it is almost miraculous that any talent at all is saved for science. These hazards are, first, the very poor quality of education; second, the higher or administrative grades of civil service – in India, the Indian administration service, and in Pakistan, its analogue, the civil service of Pakistan – which skim off the very top of the sub-continent's intellect; third, the poor chances for a promising young research student to learn to do research as an apprentice to a master scientist. The greatest obstacle of all lies in the very low probability of having the opportunity to work with a few men – in the case of India and Pakistan, the Siddiqis, the Usmanis, the Menons, the Sarabhais, the Seshachars – at the few centers of excellence, who appreciate at all the demands of research career and who run laboratories which are reasonably well equipped. There are just too few scientists who retain the creativity of which they gave promise when young and there are therefore too few to train younger scientists through a fruitful master-apprentice relationship. It remains a sad fact that, though India and Pakistan may have built specialized institutes outside the university system where advanced research is carried out, by and large their vast university systems remain weak, static and uninspired. It is not part of their tradition to make a place for advanced research or even for research at all. The colleges, which provide a large proportion of undergraduate education in India and Pakistan, have grown up in a tradition of concentrating such resources as they have on the instruction and moral formation of undergraduates. I shall always remember my first interview with the head of the premier college in Pakistan, which I joined after a spell of theoretical work in high-energy physics at Cambridge and Princeton. My chief said: "We all want research men here, but never forget we are looking more for good, honest teachers and good honest college men. This college has proud traditions to uphold. We must all help. Now for any spare time you may have after your teaching duties, I can offer you a choice of three college jobs; you can take on wardenship of the college hostel; or be chief treasurer of its accounts; or if you like, become president of its football club." As it was, I was fortunate to get the football club.

Admittedly, this was twelve years ago. I should be ungrateful if I did not mention that this same college today is contending with the Atomic Energy Commission of Pakistan for the control of high-tension laboratory with a 2.5 Mev Cockcroft-Walton set. This is a measure of the change brought about by the heroic efforts of the Pakistan Government since 1958. Things have changed. Nonetheless the situation of advanced research in underdeveloped countries still remains greatly in need of help.

In a number of fields, advanced scientific research in developing countries is beginning to reach the stage of maturity in which first-rate work can be done. Indigenous resources are being skillfully employed but there is still a desperate need for international help. The truth is that, irrespective of a man's talent, there are in science, as in other spheres, the classes of haves and have-nots; those who enjoy the physical facilities and the personal stimulus for the furtherance of their work, and those who do not, depending on which part of the world they live in. This distinction must go. The time has come when the international community of scientists should begin to recognize its direct moral responsibility, its direct involvement, its direct participation in advanced science in developing countries, not only through helping to organize institutions but by providing the personal face-to-face stimulation necessary for the first-rate individual working in these countries.

In advanced scientific research, it is the personal element that counts much more than the instructional. If, through meaningful international action, allied with national action, we could build the morale of the active research worker and persuade him not to make himself an exile, we shall have won a real battle for the establishment of a creative scientific life in the developing countries.

As an example of what is needed, I shall take the science with which I am personally associated. Theoretical physics happens to be one of the few scientific disciplines which, together with mathematics, is ideally suited to development in a developing country. The reason is that no costly equipment is involved. It is inevitably one of the first sciences to be developed, at the highest possible level. This was the case in Japan, in India, in Pakistan, in Brazil, in Lebanon, in Turkey, in Korea, in Argentina. Gifted men from these countries work in advanced centers in the West or the Soviet Union. They then go back to build their own indigenous schools. In the past, when these men went back to the universities in their home countries, they were perhaps completely alone; the groups of which they formed a part were too small to form a critical mass; there were no good libraries, there was no communication with groups abroad. There was no criticism of what they were doing; new ideas reached them too slowly; their work fell back within the grooves of what they had studied in the West or the Soviet Union. These men were isolated, and isolation in theoretical physics as in most fields of intellectual work – is death. This was the pattern when I became

associated with the University of the Punjab at Lahore; this is still the pattern in Chile, in Argentina, in Korea.

In India and Pakistan we have been more fortunate than most other underdeveloped countries in the last decade. A number of specialized institutes have grown up for advanced work in theoretical physics – the Tata Institute in Bombay, the Institute of Mathematical Sciences at Madras, and the Atomic Energy centers at Lahore and Dhaka – where a fair concentration of good men exists. But this is not enough. These institutes are still small oases. They are too small for the fertilization of the area around them. They are also in continuous danger of being dried up because the area around them is too arid and they still do not have vigorous contacts with the world community. Tata and Madras have partly solved their problem; they have funds to invite visitors – they have fewer funds to send Indian physicists abroad, mainly because of the serious shortage of foreign exchange.

It was with this type of problem in mind that the idea of setting up an International Centre for Theoretical Physics was mooted in 1960. The idea was to establish a truly international center, run by the United Nations family of organizations, for advanced research in theoretical physics. It was planned with two objectives in view: first, to bring physicists from the East and the West together, second, and even more important, to provide extremely liberal facilities for senior active physicists from developing countries.

The International Centre tries to deal with the problem of isolation in a number of ways. We have ordinary fellowships, which are given mostly to those from developing countries. In addition, the International Centre has instituted an associateship scheme. A number of carefully selected senior active physicists from developing countries are given the privilege of coming for a period of one to four months every year to the Centre with no prior formalities other than a letter to the director announcing their arrival. The Centre pays for their transportation and their maintenance. The aim is to have eventually, at any one time, a group of about fifty senior active physicists from developing countries who possess this privilege.

Looking back on my own period of work in Lahore, as I said, I felt terribly isolated. If at that time someone had said to me, we shall give you the opportunity every year to travel to an active center in Europe or the United States for three months of your vacation to work with your peers; would you then be happy to stay the remaining nine months at Lahore. I would have said yes. No one made the offer. I felt then and I feel now that this is one way of halting the brain drain, of keeping active men happy and contented with their own countries. They must be kept there to build for the future, but their scientific integrity must also be preserved. By providing them with this guaranteed opportunity for remaining in contact with their peers, we believe we are making a contribution to solving the problem of isolation.

Ideally, the associateship scheme should be wide enough to cover nearly every active physicist in developing countries. It should be well publicized, every first-rate research worker should know and feel confident that he could almost, as it were, demand its privileges if he were living in a developing country. Unfortunately, the International Centre at Trieste does not possess funds to do this. Yet the scheme is not very costly. Since it pays no salaries – only the fare and a per diem allowance – it costs us something like \$100,000. Since the associateship scheme seems thus far to be the most fruitful of all the available ways for breaking the isolation, which kills the creativity of creative scientists, it should be extended.

Universities and institutions with the wealth and scientific eminence of Princeton, Harvard, Cambridge, All Souls, Rockefeller University, New York State University, the Imperial College in London and others should seriously consider the establishment of their own associateship schemes. It ought to be considered not only for theoretical physics but for other subjects too. Rockefeller University, for example, might extend the privilege of giving its freedom not only to a scientist of the distinction of Professor Seshchar, but also to other active microbiologists in most developing countries. The European Organization for Nuclear Research at Geneva has already started a scheme similar to our own, which, I believe, covers both experimental and theoretical physics. It is designed of course only for less-developed countries within Europe (Greece and Spain). If every active, first-rate worker in the developing countries could be covered, we would go very far towards the removal of one of the curses of being a scientist in a developing land. ■



28. Sketch of Abdus Salam

11

Some Thoughts on the Role of
Science and Technology

Right from the days of Merlin at the Court of King Arthur, the scientist and the technologist have enjoyed the repute of a wizard. One of the most famous scientist-wizards of the Middle Ages was Michael the Scot, who was celebrated in verse by his countryman Sir Walter Scott in the "Lay of the Last Minstrel". A traveler to the Paynim countries of the East tells us that:

In those far climes it was my lot
To meet the wondrous Michael Scot;
A wizard of such dreaded fame,
That when in Salamanca's cave,
He lifted his magic wand to wave,
The bells would ring in Notre Dame!

We are also told Michael's words could cleave the Eildon hills in three; he could bridle River Tweed with a curb of a stone; at a sign from him you could be transported from Portugal to Spain in the space of less than a night.

We do not know if Michael the Scot did really command the powers ascribed to him. Even if he did, he could only have anticipated the technologists of Alamogordo and Cape Kennedy by just a few centuries. We may, however, with reason inquire why he did acquire in the Middle Ages the dreaded reputation that haunted his name.

Michael the Scot was a humble scholar. Born in 1175, he was one of those few inquiring men who wished to pursue science with teachers who were currently creating it. At the age of twenty-five he traveled to the Islamic University of Toledo in Spain; to study he had to learn Arabic, then the language of science. From Toledo he proceeded to Padua and Rome, teaching and translating what he had learned. His was the first translation of Aristotle's *De Anima* into Latin, not from the original Greek which Michael knew not, but from Arabic. His repute for wisdom, for wizardry, was a tribute, if you wish, to Muslim mathematics, Muslim astronomy, Muslim medicine of that day.

I have thus chosen to preface these remarks on science and technology in

Pakistan with an account of Michael the Scot. The history of science and technology like the history of all civilizations, has gone through cycles. Some seven centuries back, at least some of the developing countries of today were in the forefront of scientific and technological endeavor; they were the standard bearers, the pioneers. This was also the period of their greatest power. George Sarton in his monumental five-volume *History of Science* chose to divide this story of achievement in sciences and technology into ages, each age lasting half a century. With each half century he associated one central figure: thus 500 BC – 450 BC, Sarton calls the Age of Hippocrates; 450 BC – 400 BC is the Age of Plato. This is followed by the half centuries of Aristotle, of Euclid, then of Archimedes and so on. From 650 AD – 700 AD is the half-century of the last great Chinese scientist I-Ching. From 750 AD in an unbroken succession for three hundred years, are the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Omar Khayyam – Arabs, Turks, Afghans and Persians – men belonging to the culture of Islam. Around 1100 AD appear the first Western names, but the honors are still shared between the East and the West for two hundred years more. From 1350 AD, however, science was created only in the West. The East had lost its technological superiority and with it also its political integrity. No wonder then that Michael the Scot, in 1200 AD, had to travel to Toledo to complete his education. No wonder that this association with the infidels earned him an excommunication. No wonder that Dante consigned him to Hell.

I started this article by remarking that the scientist and the technologist have throughout the ages enjoyed the repute of wizards both in peace and in war. Starting with Archimedes at Syracuse, right up to the age of Oppenheimer and Teller at Los Alamos, the technologist and scientist have determined in a large measure, the might, the respect and the place of any community in the comity of nations. It is hardly surprising that the years of creative science in Islam were also the years of its greatest strength and integrity. The direct relationship of technological superiority with influence as well as prosperity has perhaps received no expression more eloquent than that of Whitehead: "In the conditions of modern life the rule is absolute: the race which does not value trained intelligence is doomed. Not all your heroism, not all your victories on land or at sea can move back the finger of fate. Today we maintain ourselves. Tomorrow science will have moved forward yet one more step and there will be no appeal from the judgment which will be then pronounced on the uneducated."

With the coming of Pakistan the Muslim nation has once again entered a new period of revival. If this revival is to endure it is absolutely imperative that the nation goes back to the fountain-spring of all strength – scientific and technical skills. There is no reason whatsoever why men from Pakistan should not be in the van of scientific achievement just as their forefathers were; there is

no reason why the country should not have first rate technicians, skilled craftsmen, skilled agriculturists. This is the capital, which we must build as feverishly as we possibly can.

In this note I will not discuss the high level scientific manpower. Its shortage in Pakistan and the causes for this have been discussed elsewhere. Here I shall merely illustrate my remarks regarding the lack of skills by a set of figures for training and education at the secondary and pre-university stage. Around the age of sixteen or so there is a bifurcation between the vocational and technical streams of students versus the non-vocational in almost all countries. This list of "non-vocational" students includes all Arts men, all future lawyers, all future managers and others. Taking a typical advanced country like Germany, the percentages which obtained between the two streams in the year 1961 were the following:

<i>Germany</i>	Secondary (non-vocational)	41%
	Technical and Vocational	59%
<i>Pakistan</i>	Non-vocational	99%
	Technical and Vocational	1%
<i>Pakistan</i>	<i>(at the end of Third Plan)</i>	
	Non-vocational	94%
	Technical and Vocational	6%

These figures give the whole story of why the country is backward. Just a few days ago, the Institute of Development Economics at Karachi reported some figures for Karachi itself. Karachi is fortunate that it is able to impart education to some thirty-five percent of the total school-going population of the city between the ages of five and twenty. Of this thirty-five percent no more than one percent are receiving vocational training of any kind. The reasons for this tremendous imbalance are historical. The reasons are connected with the pattern of education, which the British left us. This pattern must die. The number of skilled men have to be multiplied. It can be done but it would be a fallacy to imagine that this is the duty of the State alone. Every industrial enterprise employing skilled labor owes to the community to give back to it skilled and trained apprentices; not only for use within the enterprise itself but also for other nascent enterprises. The community has to participate in this tremendous "jihad"; the nation can gear itself to the task of reaching a more balanced proportion between vocational, technical, and grammar school type of education during the next ten years. Therein lies the key to national survival. ■

12

The Advancement of Science for the Developing Countries

I shall be concerned in this paper with the possibilities of growth of indigenous traditions in basic and applied science in the developing world. I believe that the present situation as well as the future prospects of such a growth are bleak. The facts are easily stated. Of industrial science very little exists. This is because most industry in developing countries is based on processes bought from abroad; alternatively, the industrial concerns belong to foreign companies, who prefer to undertake whatever new industrial research and development is needed in their own strong foreign-based research laboratories. Among industries I am cynically including the one great source of scientific strength in any country – the weapons industry. The second area, which one might have imagined would receive the topmost priority relates to sciences as applied to exploitation of indigenous resources. This includes agricultural sciences, soil sciences, mineral sciences, medical sciences in relation to local diseases and population problems. These are areas where the relevant scientific knowledge may not be available in the world supermarket and new knowledge needs to be created. Measuring scientific activity through the existence or lack of strong centers of research, barring a few outstanding examples of institutions internationally set up – and these I shall be speaking about later – there are unfortunately not many centers of outstanding worth. The reasons for this are well known. Basically they stem from the general apathy of those responsible for economic development to invest in local science; from the lack of trust in the capabilities of their own scientists, and reciprocally of the non-involvement of local scientific communities in the exciting problems of development. Finally, fundamental research in the universities or outside – again barring some very few exceptions in India, Argentina, Pakistan and Brazil – is weak for two well known reasons.

- 1) The towering men of science produced by most developing countries, finding the atmosphere in their own countries sterile, have tended to leave.

- 2) Those who are left behind are isolated and do not form part of the international world community.

Thus the two promises of science, the one relating to economic development and the second relating to intellectual fulfillment, both remain unrealized.

The weakness of science and scientific institutions is not due to lack of lip service paid to the ideals of science and need for its development by leaders in the developing countries. Notwithstanding this lip service, however, the fact remains that the scientific revolution of thought has hardly touched the developing world. There is no comprehension of the scientific style of the natural world, no intellectual transformation of society as a whole. The energies of most intellectuals in developing countries are occupied either with problems which arise from the local conflicts with those in the neighboring countries or with problems arising from real or supposed economic and other exploitation of their countries.

My purpose in speaking to a forum like this one is that the situation in the developing world is so bleak that without active involvement of the international scientific community it will not change. My thesis is that indigenous science in the developing world is weak, but that it should expect and demand, as it were of right, fullest support from science abroad. We scientists pride ourselves as being the last of the idealists, our motives are not politically suspect, we fortunately possess a fund of goodwill through the work of the institutions which include private foundations, as well as the scientific Agencies of the United Nations family.

The involvement of the world scientific community and the help it can give to the weak scientific communities in the developing countries can take many different forms. I shall describe only some of the possible ways. In particular, I shall concentrate on some of the institutional means the world community may possibly use. But this is in no way meant to minimize the importance of the other means which I shall not talk about. The crucial point is a realization on the part of the world scientific community that here is a sphere where they can directly help and they are expected to help.

But before we can make an assessment of what is needed today I feel it is important to get an idea of the past, particularly of why it is that the developing world, and particularly those parts of it with glorious traditions of a scientific past, have been so tardy in achieving the modern scientific transformation. Since personally I am most familiar with my own, the Islamic civilization, I shall select my illustrations from its history.

Almost exactly twelve hundred years ago, Abdullah Al-Mansur, the second Abbasid Caliph, celebrated the founding of his new capital, Baghdad, by inaugurating an international scientific conference. To this conference were invited Greek, Nestorian, Byzantine, Jewish, Chinese, as well as Hindu scholars. From this conference – the first international conference in an Arab country – dates the systematic renaissance of science associated with Islam. The theme of the conference was observational astronomy. Al-Mansur was interested in more accurate astronomical tables than were available then. He wanted, and he

ordered at the conference, a better determination of the circumference of the earth. No one realized it then, but there was read at the conference a paper destined to change the whole course of mathematical thought. This was a paper read by the Hindu astronomer, Kankah, on Hindu numerals, then unknown to anyone outside of India. Kankah had come to the conference to present to it copies of various *Siddhantas* – the Hindu manuals of astronomy.

Al-Mansur's conference succeeded beyond all expectations. It laid the foundations of astronomical and mathematical studies in Islam; from this conference grew the idea of the founding of one of the world's first *international* Academies for Scientific Research, the Bayt-ul-Hikma. But even on the more practical, more pragmatic plane, from this conference date the architectural and engineering studies of Naubakht and Mashallah, both of whom attended its sessions and who were later responsible for some of the major monuments of Baghdad. From this conference dates the craft of instrument making in Baghdad, whose specimens still survive in the masterworks of Isa Asturlabi.

The fact that there was collected at Baghdad this concourse of scholars, forming an international gathering, was not purely accidental. The Arabs were building on the heritage of Greek science, the custodians of which at that epoch of history were the Nestorian Christians who, bitterly persecuted by the Byzantines, had emigrated to Mesopotamia, and later to South West Persia, from the sixth century onwards. They had made a home at Gondisapur, not far from Baghdad. They possessed, in Syriac, translations of works of Plato, Aristotle, Euclid, Archimedes and Hippocrates. The existence of this Nestorian Hellenistic center of learning, Gondisapur, was Allah's gift to a new civilization, then bursting with youthful zest and fired with the Prophet's injunction to value science and learning above everything else. On this foundation, carefully nurtured, the Caliphs in Baghdad built, importing also Chinese and Indian scholars.

The next four hundred and fifty years saw the brilliant flowering of Islamic sciences and learning, both in Eastern Islam as well as in the West, in Spain. What during this period was the attitude of Western Europe towards this outpouring of knowledge? In Charles Singer's words: "This attitude was the same which the Oriental now has towards the West. The Oriental recognizes that with the West are science and learning, power and organization and business enterprise, but the admitted superiority of the West does not extend to his sphere of religion. He gladly accepts Western standards of economics, technology, science and medicine, but repudiates and perhaps despises the religion, philosophy and much of the social outlook of the West. In the Europe of the tenth and eleventh centuries it was exactly the opposite. The West knew full well that Islam held the learning and science of antiquity. Muslim proficiency in arms and administration had been sufficiently proved." But with this longing for the intellectual treasures of the East, there was fear that Christian values and

Christian culture would be deleteriously affected. Thus no attempt was made to borrow or to make contact. An eloquent expression to these fears was given in a lament by Alvaro of Cordoba writing in the ninth century: "Many of my co-religionists read the poetry and tales of the Arabs, study the writings of their scientists and philosophers, but where are those among us who can read the Latin commentaries on the Holy Scriptures? Among thousands of us there is hardly one who can write a passable Latin letter to a friend, but innumerable are those who can express themselves in Arabic and compose poetry in that language with greater art than the Arabs themselves."

This feeling of repugnance on the part of the West lasted some three to four hundred years. It then began to change. It is not commonly recognized how important the last half of the eleventh and the first part of the twelfth century are for the development of the European science and European civilization. For some reason there arose in Italy, France, Scandinavia and Britain a number of men who were willing to brave the disapprobation of the Church and its odium in order to make available to the West the learning of the East and the international intellectual treasures of humanity garnered and improved upon by the Arabs from Greece, India and China.

One of the most important among these men was an impoverished Scotsman who left his native glens to travel south to Toledo in Spain, some seven hundred and fifty years ago. For my second historical illustration I shall consider the life and work of this Scotsman. His name was Michael, his goal to live and work at the Arab universities of Toledo and Cordoba. Michael reached Toledo in 1217. Toledo was an Arab town but not then in Arab hands. It had been captured by the Spanish Christians a hundred years before, but the tradition of Arabic learning, Arab teachers and language remained intact. One may note the parallel with the international center of Gondisapur of the Nestorians five hundred years before, which had been captured by Islam but had retained its Christian identity. In Toledo, Michael the Scot formed the ambitious project of introducing Aristotle to Latin Europe, translating not from the original Greek, which he did not know, but from the Arabic translation of Aristotle then taught in Spain. Exactly one hundred years before, Adelard of Bath, an Englishman, had done a like service for geometry by translating Euclid into Latin, not from the original Greek, but also from an annotated Arabic translation.

Toledo's school, representing as it did the finest synthesis of Arabic, Greek, Latin and Hebrew scholarship, was one of the most memorable of international assays into scientific collaboration. To Toledo and Cordova came scholars, not only from the rich countries of the East – like Palestine and Egypt – but also from developing lands of the West – like Scotland. Then, as now, there were obstacles to this international scientific concourse. First, there was the political division of the world. In 1217, the wounds of the Third Crusade, fought barely

thirty years before, were still not healed. And then there was the economic and intellectual disparity between different parts of the world. Men like Michael the Scot and his contemporary in Toledo, Alfred the Englishman, were singularities; they did not represent any flourishing schools of research in their own countries. With all the best will in the world, their teachers at Toledo doubted the wisdom and value of training them for advanced scientific research. At least one of his masters, despairing of his lack of grounding in science, counseled young Michael to go back to the clipping of sheep and weaving of woolen cloth.

Added to Michael's lack of background training, there was the disapprobation of the Church I have spoken about. Michael's countryman, Sir Walter Scott, in his "Lay of the Last Minstrel" has given expression to this disapprobation. The minstrel in Scott's poem tells us how Michael was accused of wizardry and other deadly sins:

On those far climes it was my lot
To meet the wondrous Michael Scot;
A wizard of such dreaded fame,
That when in Salamanca's cave
He lifted his magic wand to wave,
The bells would ring in Notre Dame!

The lay goes on:

When Michael lay on his dying bed
His conscience was awakened.
He bethought him of his sinful deed
He gave me a sign to go with speed.

But nothing could save Michael's soul. Dante found Michael in agony in one of the lowest circles of the Inferno – all for the deadly crime of learning Arabic and teaching Europe the Arab sciences of mathematics, biology and philosophy.

Another two hundred years were to pass. During these two hundred years, the devastation caused by the Mongols and Tamerlane destroyed all tradition of scientific inquiry in the lands of Islam. The tables were now completely turned; it was the Muslim scholar who had turned inward; inward towards the spiritual security afforded by his past cultural tradition; shunning all contact with newer thought which came now from the Western lands. One of the last of the great scholars in Islam, Ibn-Khaldun, whom Toynbee describes as a man who conceived and formulated a philosophy of history which remains the greatest work of its kind that has ever been created by any mind at any time at any place – even a man of such caliber, writing two hundred years after Michael the Scot, in 1400 AD, about sciences in Christian lands expresses himself thus: "We have heard of late that in the land of the Franks and on the northern shores of the

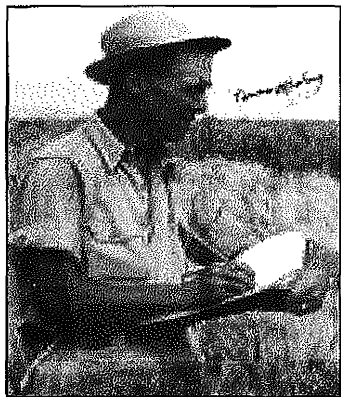
Mediterranean there is a great cultivation of philosophical sciences. They are said to be studied there again and to be taught in numerous classes. Existing systematic expositions of them are said to be comprehensive, the people who know them numerous and the students of them very many. Allah knows better what exists there but it is clear that the problems of physics are of no importance for us in our religious affairs. Therefore we must leave them alone." Ibn-Khaldun displays no curiosity, no wistfulness; just apathy bordering on hostility.

I could give parallels from the other two great world civilizations, the Chinese and the Hindu. As far as we know, the pattern is more or less the same; the initial borrowing from an *external* intellectual tradition – and, I wish to stress *external* tradition – possibly at an international intellectual center; the great diffusion of learning in the society, its wholesale acceptance of the scientific spirit of inquiry and then finally the closing in of mental barriers once again.

How can this situation be changed? I said earlier that a crucial initial role was played in building up science in Islamic and Christian civilizations by the essentially alien international centers of Gondisapur and Toledo representing traditions of living science in the midst of their own societies. I believe that something similar to these centers will have to be created in the developing world before it begins to enter into the spirit of a true scientific revolution. Nothing can give that instinct of what is credible and what is not, that fine sense of the scientifically genuine and the scientifically deceptive, as the direct experience of living science – living in your own conditions and environment and flourishing within your own cultural tradition. The problem, which concerns us today is this: Can we capture or create the Gondisapurs and Toledos of today by our own efforts unaided within our countries? By and large, the answers appear to be: No! The reasons are simple. Science feeds on science. Men of science wish to work where other such men are and where they obtain facilities. We in the developing world cannot or will not afford these facilities, either through actual poverty, or through a poverty of spirit; far from attracting the foreign great men, we are likely to lose our own, retarding thereby still further the scientific transformation of our societies.

To re-emphasize my point, let us look more closely at the overall situation in the developing countries and ask ourselves what are the first-rate institutes there which have made the most impact intellectually or in terms of economic returns. Two such outstanding institutes immediately spring to mind. These are the International Rice Research Institute (IRRI) in the Philippines, set up with Ford and Rockefeller assistance, and the International Wheat and Maize Institute (CIMMYT), similarly sponsored, in Mexico. One of the greatest revolutions, unpublicized so far, but potentially something as great as the industrial revolution itself, is the agricultural revolution, which has been taking place in the

last three years in parts of the developing world. This revolution we owe to the work done at these two institutes. As you are aware, the bulk of the gross national products of poor countries come from agriculture. Unfortunately, the wheat and the rice and the cotton and the maize, which we raise have had very low yields. This was not due to any sloth or perversity or incompetence on the part of our farmers. It simply was the result of the genetic varieties that thrived without any diets of nitrogen. The introduction of a nitrogen-consuming Japanese variety of rice in India, for example, simply failed, for India, oddly enough, does not have the same long hours of sunlight as Japan.



29. Nobel Peace Laureate Norman Borlaug at CIMMYT, Mexico, 1972



30. World Food Laureate H.M. Beachell with U Thant, UN Secretary General and R.F. Chandler, Director, at IRR1, 1970

The last few years have seen great advances in plant engineering. These advances have for the first time been purposefully applied to create new dwarf varieties of wheat and rice. The wheat research was carried out in Mexico, the rice research in the Philippines. The ideal rice plant, I understand, was literally designed on the drawing board; the roots of so much thickness, the stem, the stalk, the ears, the numbers of grain in each ear, the amount of sunlight it might receive. Likewise for rust-resistant wheat, with short, stiff straws to avoid "lodging" of heavy-headed plants, insensitive to differences in diurnal rhythms of sunlight and dark. The new varieties were tried on a large scale in India and Pakistan for the first time on some thirty million acres in 1967-68. The wheat crop yields went up by as much as 300% - the rice, in some instances, by 500%. This summer there was a shortage of agricultural labor in West Pakistan - the first time perhaps in history - there was so much to lift and reap. Wheat production in Pakistan has gone up from 3.8 million tons to 7 million tons; it is expected to increase at 10-15% per year for a number of years; Pakistan is worrying about a wheat glut.

Why were these international institutes able to work a miracle, which no national institutes could? The reasons I think are not far to seek. The atmosphere of scientific pursuit as we understand it, the caliber of men that could internationally be assembled, the facilities that could be afforded, the contacts with the rest of the scientific community, the flow of information; all simple things which one takes for granted and which simply are not available or made available in the developing countries themselves.

Will the example of these institutes implant the true scientific ideals in the surrounding countries? Will they be imitated, their example followed? Will they bring the scientific revolution I have talked of before nearer? I believe so, I hope so. For one thing, for the first time the miracle wrought by the work at these institutes has convinced our hard-headed administrators that applied science is worth spending money on. To this symposium has been presented a proposal to establish an international center on insect physiology and endocrinology in East Africa. I find it an exceedingly exciting proposal. It carries with it the promise of a scientific frontier field in a problem, which is at the same time closely related to actual needs of the developing world. It promises to attract leading men of world science to work in the developing world and help to bring about the scientific revolution. Given thirty or forty such institutes around the developing world, I feel a real scientific transformation will come about.

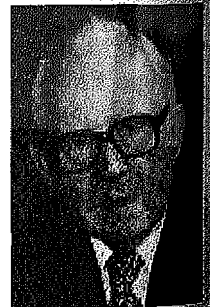
I have spoken of the modern parallels of Gondisapur and Toledo, centers of scientific excellence set up in developing countries in conjunction with local universities or outside them, but backed strongly by the international science community. One of the important problems which arises in connection with such centers is: how should they be sponsored? The Wheat and Rice Institutes were set up by *local governments* with help from two of the highly respected scientific foundations. In addition to these foundations there is one other – and indeed potentially an even more important – non-political resource, which we as a community have not fully exploited. This is the United Nations Organization and its scientific Agencies. The United Nations is a much maligned institution; most of us are conscious of only one side of its activities, the political, embodied in the Security Council. Very few of us know of its far-reaching social, economic and scientific work. The scientific work is concentrated in its specialized agencies: the Food and Agriculture Organization, with an annual budget of \$30 million; the World Health Organization with a budget of \$50 million; the United Nations Educational, Scientific and Cultural Organization, with a budget of around \$30 million; and in a category by itself, the International Atomic Energy Agency, with a budget of \$10 million. These are very modest sums, but in addition the United Nations itself dispenses some \$100 million on science and technology through the United Nations Development Fund. These budgets are contributed by member nations according to a formula based on their gross

national products. The specialized agencies dispense the funds for providing technical assistance to developing nations; they award fellowships and sponsor conferences and symposia. To coordinate the work of these Agencies, and to pinpoint newer areas where science and technology may make a direct impact, there is the United Nations Advisory Committee on Science and Technology, of which I have the privilege to be a member.

As an example of the exploitation of the United Nations machinery for pure science, I shall take the case of an international institute for the developing countries, in whose setting up I was personally associated. Unlike the other institutes I have spoken about, it is not an international institute located in a developing country, though it could have been. By speaking about it I wish to illustrate an important anti-brain-drain device to end isolation of leading scientists from the developing countries which was pioneered at this institute and which may have applications throughout the scientific field. You may have noted that the scientific effort of the United Nations family has so far been mainly oriented toward applied science. A natural extension of this work would be to charge the Organization – with its unique inbuilt supranational structure and its collective use of available resources – with responsibilities also toward fundamental science, and this would naturally include responsibilities to the pure scientists from developing countries.

In September 1960 I had the privilege for the first time of attending the General Conference of the IAEA as a delegate from Pakistan. It seemed to me a good thing to try to make at least a beginning toward an international United Nations University, benefiting university scientists both from developing as well as developed countries, by proposing to set up a post-graduate Center for Theoretical Physics under the IAEA auspices. With the co-sponsorship of the Governments of Afghanistan, the Federal Republic of Germany, Iran, Japan, the Philippines, Portugal, Thailand and Turkey, we introduced a resolution on behalf of the Pakistan Government, suggesting that an international center for research in theoretical physics should be set up under the auspices of the IAEA. In consonance with the standard UN practice, the resolution started with a preamble which stressed the unique virtues of theoretical physics for peace, prosperity and health of mankind.

Of the list of nations first sponsoring the idea, most were the less-privileged countries. It was clear that the setting up of such a center was of interest to these nations, for the hope was that it might help in resolving one of the frustrating problems which their active university physicists face – the problem of isolation. Such men could come frequently to a center of this type, not to stay permanently but to renew their contacts and then to go back refreshed after a period of



31. S. Eklund

concentrated research. This would not solve the problem of heavy teaching duties in their own countries, it would be no substitute for building up centers of excellence in their own countries, but it would certainly end one aspect of their disabilities – isolation from newer ideas.

Right from the outset the idea met with enthusiastic support from the IAEA's directorate, particularly from its distinguished Director General, Dr. Sigvard Eklund, whom you well know, as well as from the physics community, two of our most ardent sponsors were Niels Bohr and Robert Oppenheimer.

After four years of intense behind-the-scenes effort, the Board of Governors agreed to set up such a center, for a trial period of four years, provided the bulk of the finance for it could be found outside of IAEA funds. The reluctance of the Board of Governors was not unrelated to the fact that the IAEA's total budget of \$10 million is itself an extremely modest one. Offers of financial assistance from interested Member States were solicited; of four received (from the Government of Italy for a center to be located at Trieste, from Denmark for Copenhagen, from Pakistan for Lahore, and from Turkey for Ankara) the most generous, and one which no developing country could hope to compete with, was the Italian Government's offer for Trieste. The moving spirit behind it was Professor Paolo Budinich, Professor at the University of Trieste. This offer was accepted and the Center started functioning in October 1964 with a mandate until October 1968. This has now been extended for a further six years; furthermore, from 1970 onwards UNESCO has decided to participate as a full partner with IAEA in financing and running the Centre.



32. P. Budinich

Some of you may be familiar with the Centre and what it has achieved during the last five years. The Centre receives as visitors leading physicists; in principle from one hundred but in practice from around fifty nations – thirty of these developing. These men come to work on their own research problems in the milieu, which they themselves create. In this the Centre does not differ from any other research center in theoretical physics, except perhaps in the jealously guarded high standards it tries to maintain. Where it does differ is in the easy formality with which it can arrange long-term contact between physicists from the East and the West – this is possible because the Centre is a United Nations sponsored Institute and not a national one – and even more important, of physicists from developing countries. To break the barrier of their isolation, the Centre has pioneered what it calls an associateship scheme. I shall describe it, for, as I said it possesses wider applications outside the Trieste Centre. An associate in our terminology is a physicist working in a developing country who

is simultaneously a member of the Centre's staff. Once elected he can come to the Centre every year for a period ranging from six to twelve weeks, with no formalities except a letter announcing his arrival. With a generous grant from the Ford Foundation the Centre pays the associate's fare and his expenses at Trieste; the associateship lasts for three to five years and is renewable. The intention is to try to cover all top active men in the developing world and to give them this financially-guaranteed possibility of remaining in touch with other leading men in their subjects. The crucial feature of the scheme is the stability of the three to five years which it provides a leading man in a developing university to plan his work and career. The one important pre-condition for remaining an associate is that nine months of the year must be spent in the developing country itself.

We received this year a generous grant from the Swedish International Development Authority to create twelve associateships for African professors. Our total at present is thirty-five; I am hoping that some day soon my dream of being able to finance one hundred associateships for front-rank active theoretical physicists will be realized.

There is nothing special about theoretical physics so far as the associateship scheme is concerned. There is no reason why other institutes in other subjects may not start similar schemes to ours to end the problem of scientific isolation. Every university in the developed world can do this – by appointing five to ten associates in any discipline it may choose ending thus once for all the problem of isolation of scientists from developing countries. The United Nations Advisory Committee, at a recent session in New York, took the initiative to convene a meeting of US University Presidents and Heads of US private foundations to set up in conjunction with the United States Academy of Sciences and the Canadian Research Council a scheme catering in this manner for between two hundred to three hundred scientists. The Canadian Research Council has already started its own scheme of associateships or dual appointments of those leading men who have in the past received their research training in Canada. We are still waiting for the United States' action.

The ideas I have spoken of form part of the greater idea of setting up a world federation of research institutions which may or may not have connections with the United Nations Organization but which could be affiliated to a world university. This is the idea to create a world federation of existing international postgraduate institutes for advanced study which may constitute a first step towards the achievement in the future of the bigger ideal of a fully-fledged world university. The essential element of the plan is to identify presently existing research institutions of first rate quality which are international in character and in terms of their faculties. All such institutions – if they exist in the developed world – may pledge to reserve perhaps 20% of their resources and facilities towards supporting the work of high-grade scholars from developing countries.

through associateships, dual appointments or other devices. Such Institutes, together with the International Institutes I have spoken about in the developing countries – both in pure and applied sciences – as well as in Economics, Sociology and other studies of man – would make up a Federation, enriching each other by contacts, deriving strength from common ideals shared and practiced. As I said I would like to see such a Federation linked up with the United Nations Organization or one of its Agencies in a loose connection. Most scholars feel frightened of a possible deadening hand of the United Nations machinery. From personal experience with the Trieste Centre I can vouch for it that their fears are exaggerated; on the other hand the advantages in terms of true internationalism are very real and immense. In sciences, in scholarship, when we speak of internationalism, most thought goes to contact between the East and the West. The thesis of my remarks today has been that there is the Third World, very much wishing and very much deserving to come in as equal third partners. The United Nations system has the merit that it constantly reminds one of this.

Before this Federation of World Institutes begins to look like the World University in the sense most of us understand the University concept – and this applies equally even if we limit our sights to a postgraduate University – new Institutes, with tasks relating to universal studies relevant to man's state, will have to be created to link up with this Federation. But the first step – the Federation – could perhaps come even within the next ten years. In all my remarks I have throughout assumed that the scientific community recognizes that it is part of its mandate to build up true internationalism. We who pursue scientific inquiry as a profession find the international ideal something bred, as it were, within our bones. The very exigencies of scientific creation demand that in this pursuit we recognize no color, no creed, no political persuasion. Most of us believe in this passionately, not just as one more measure towards internationalizing this planet, but also for much more practical reasons. We believe that science offers the one sure way of abolishing the vast slum on this earth inhabited at present by two thirds of mankind – a slum which no modern nation-state would tolerate in its midst but which we collectively do on the global scale.

The international ideal was never expressed better than by the seventeenth century mystic, John Donne: "No man is an island entire of itself; every man is a piece of the continent, a part of the main. If a clod be washed away by the sea, Europe is the less, as well as if a promontory were, as well as if a manor of thy friend's or of thine own were. Any man's death diminishes me, because I am involved in mankind; and therefore never send to know for whom the bell tolls; it tolls for thee. ..." ■

13

The Permanently Rich and Permanently Poor

I appreciate your kind courtesy in permitting me to make a brief comment on Prof. Harrison Brown's paper.

I am sure all of us are most grateful to Prof. Harrison Brown for his thoughtful, wise and constructive contribution. His picture of a division between the more or less permanently rich and permanently poor humanity is frighteningly true. As Prof. Harrison Brown has said, the moral, the spiritual and even the political issues this crisis of humanity raises are immeasurable. In Gandhi's immortal phrase, "to those who do not get their two meals a day, even God dare not appear except in the form of food." Today we can still afford to speak about this crisis in detached, somewhat sorrowful tones. Tomorrow it may become too serious – as Prof. Magat suggested on Sunday – a conflict of the haves and have-nots predicted as far back as 1945 by Aldous Huxley. His were not idle, irresponsible words. For as long as there remains one reservoir of armaments accessible to poorer humanity, a world as polarized as ours is fundamentally unstable and will not endure.

But why are we so desperately poor? Prof. Harrison Brown has enumerated various factors: high birthrates; lack of understanding of tropical agriculture; inadequacy of investment capital. To my mind the most crucial point he has made, however, is that development and all factors involved in it are closely interrelated. For example, birth control measures will not succeed for the next fifteen years, firstly because we cannot foreseeably afford and develop social security measures to replace the old-age security provided by male children; secondly, they will not succeed until basic health services are developed to the pitch that women can safely trust these services for any mishaps that might occur. We therefore are, in Prof. Brown's phrase, in a most unfortunate feedback loop where poorness intensifies poverty.

Among the factors not mentioned by Prof. Brown is the crucial one of ever-falling commodity prices and ever-rising industrial prices. Prof. Garcia is going to elaborate on this, but it sometimes appears to us in the poorer world that we in our humble way are helping to finance some of the continually rising living

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standards of the rich. During the ten years between 1955 and 1965 Pakistan received one and a half billion dollars in what are euphemistically called adverse terms of trade. If all aid had been withdrawn and only the prices had stood still at the level of fifteen years, we would probably have done no worse. And the situation grows yearly more bleak with increasing economic discrimination against our semi-manufactures in the developed markets. A ton of cocoa beans cost £200 landed in France. Crush the cocoa beans, grind them immediately there is a 150% tax levied on this so-called manufactured commodity within the European Economic Community. It is heartless, it is cynical to say this, but one really wonders if the EEC wishes to forbid Nigeria and Ghana from reaching even this much of industrial maturity. The same story repeats itself with Indian iron ore when converted to pig iron. In recent years we have heard of tremendous concern against the technological gap developing between the US and Europe – of the enormous price Europe must pay for technological processes, patents, specialized materials which it must import. Multiply this technological gap by a factor of a hundred; imagine your country is at the mercy of a foreign technical firm, unmotivated by any of the Pugwash ideals, unrestricted by any effective competition, using what it cavalierly tells you are after all long-range loans or outright grants and you may perhaps understand some of our cynicism; some of our resentment at the patchy, often wasteful, uncoordinated aid programs of today. And not only are these programs patchy, – and here I might disagree somewhat with Prof. Harrison Brown's presentation – it just is not true that the developing world would not be able to absorb the extra funds if the world loan and aid facilities were doubled tomorrow on account of lack of trained manpower. In my view, the few countries which have made a relative success of their development plans in recent years – countries like Formosa, Philippines, Kenya, even Pakistan were fortunate to receive help above the magic par line of three dollars per person per year. They certainly had no more trained manpower than those unfortunate ones below this magic line, countries like India, Brazil or Argentina, the problem of whose trained manpower exports have occupied at least part of a working group's time. This manpower may not be properly trained for development tasks but they possess the basic training. With the experience already gained it would not take decades to use them if funds were available. But I am really being ungrateful; I could not endorse strongly enough Prof. Harrison Brown's pleas for a multinational capital and technical pool. The crucial question, however, which we must ask ourselves is how we in the Pugwash movement can accelerate its creation, how we can convey to those who make decisions the intensity of our feelings. The Secretary General spoke on Sunday of the Continuing Committee's suggestion to promote in smaller Pugwash conferences, studies in depth of selected problems, related also to development. But we from the developing countries hope for something more. To illustrate, let me take the recent example of a study in depth on the World Protein Gap, commissioned by the United Nations Advisory Committee on Science and

Technology – a committee in some ways parallel to the Pugwash. This report was prepared after eighteen months' work by the ablest world scientific talent available; it recommended to the Economic and Social Council of the United Nations a 13-Point plan of action; it recommended the setting up of a voluntary Protein Promotion Fund of 500 million dollars over ten years. The Economic and Social Council of the United Nations met in July this year. The Advisory Committee had succeeded in convincing some of the developing countries to start the debate, to sponsor the Protein project and to pledge their share of costs. The UN Council met; it politely thanked the scientists for their worthy efforts, and proceeded then to shelve any mention of the 500 million dollars; ending in its judgment the whole episode.

I am bringing this concrete case up because to my mind this should never be the end of the road. This is precisely where Pugwash as the moral conscience of the Scientific Community will have to learn to strike, to exercise its influence. We, as scientists, know better than anyone else that three hundred million of world's children, who are currently deprived of protein between the ages of one and seven are under a sentence of having their learning process impaired permanently and irreversibly – of becoming second class citizens, a drag on humanity, even if they survive. I believe the Continuing Committee, the national Groups, all of us can and should mount a crusade on issues like this one lending our individual and collective voices educating those who make the final allocation of funds. I have seen within my own humble experience how a determined effort by Pugwash scientists with their own Governments can succeed. My example does not have the global significance of the Test Ban treaty, but it does illustrate what can be done. In 1960, at the International Atomic Energy Agency, a group of physicists from the developing countries proposed the creation of the first Centre of excellence for pure science under the aegis of the United Nations. They were opposed by delegations from the US, USSR, UK, France, Canada, Belgium, Holland, Australia – in fact, from almost all the advanced countries. Two years later at the same forum, at the same meeting, the same resolution was carried through unanimously this time. During these two years, the Pugwash physicists had been at work. Most of these physicists are here, sitting in this audience. I shall not name them. But their persistent persuasion with their own governments carried the day. I am equally confident two years from now, the 500 million dollar Protein Project – indeed the international pool Prof. Harrison Brown spoke about – could equally come into existence if we truly bend our energies to it. I would like to end by recalling something which happened six hundred years ago.

On a cold January morning in the year 1401, the greatest philosopher-historian of Islam, Ibn Khaldun, was lowered at his own request by long ropes over the city-ramparts of Damascus. Damascus, at that time, was beleaguered by

the Tatar hordes of Timurlane of Samargand. Timurlane, the world conqueror, had a few years before sacked Baghdad, then Delhi, then Moscow. A trail of devastation and death had followed his Tatar armies everywhere. It appeared that day six hundred year ago that the fate of Damascus was sealed. Ibn Khaldun, on a one-man self-appointed mission, hoped to plead with Timurlane for a reprieve for the life of Damascus. Ibn Khaldun was a native of Tunis. He had been visiting Damascus and was now caught in the siege. Some twenty years before, he had completed in Arabic his master-work on Universal History. In Arnold Toynbee's words, "Ibn Khaldun had conceived and formulated a philosophy of history which undoubtedly remains the greatest work of its kind that has ever been created by any mind, at any time, at any place." With nothing but the courageous assurance of a true scholar to sustain him, the seventy-year old philosopher-historian trusted in his ability to influence the semi-literate Tatar, with whom he could converse only through an interpreter.

History has preserved an account of this encounter. Timurlane attempted to bend the interview to his ends as a military leader would; he minutely questioned the scholar on the military routes to Cairo, Tunis and beyond. Ibn Khaldun on his part resolutely parried. His was a humanitarian mission; he would not let his knowledge serve any future ventures of the Tatar. In the end, the scholar's integrity won; his word prevailed. Timurlane signed a reprieve. Damascus was saved.

Whenever I think of this heroic, this courageous act of a great scholar, it imparts a glow to my heart. To find an individual parallel today, one would have to project a Weisner, or a Cockcroft, or a Rotblat pleading and succeeding in obtaining a reprieve for Hanoi. To find a collective parallel, one has to come to the Pugwash movement.

Like Ibn Khaldun, we all owe a moral responsibility to save humanity in this grim crisis where it sometimes appears to us as if two distinct species are inhabiting this same planet. Like Ibn Khaldun, we can, we must succeed. ■

14

Memorandum on a World University

A number of groups have been working independently towards the concept of setting up one or more world universities. That at least one such university did not come into existence at the same time as the United Nations in 1945 is something of which the world's academic and scientific communities cannot feel proud. It is imperative that practical steps be taken in the nearest future to ensure that we see one or more truly international universities take shape during the next twenty years.

The plan envisaged here is one way of progressing towards this objective. It has the merit that nucleating points exist already, and it could find implementation in as little as five years.

I do not have to recount the difficulties, which are likely to be met in implementing the idea of a full-fledged, conventional university. Since the sums of money involved are likely to be large, it is out of the question that the UN – even with the support of the World Bank – could finance such a venture. It is also unclear if one could get a number of the richer countries passionately interested in a project of this type and ready to back it. There are too many casualties among proposed international or regional institutions in the academic field already to give great hopes of success unless one proceeded in a gradual manner. Further, the choice of location in one country in preference to another will always present difficulties. Even the choice of which faculties to develop first is not going to be plain sailing.

This note, then, is not concerned with a university in the conventional sense – an institution devoted both to teaching and research. We shall here be concerned with research only. The plan is to create a world federation of international institutions for advanced study in various disciplines, which may constitute a first step towards the achievement in the future of the large ideal of full-fledged world universities of the conventional type. It is the basic premise here that it would be tragic if world universities, and likewise the federation proposed, were not linked right from the outset with the United Nations. Even though imperfect, the UN provides the one means that exists today to ensure that in academic institutions set up under its aegis politics and scholarship may be separated from each other. Second, the most important, it is the one real guarantee of true internationalism,

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the one avenue which can ensure that scholars from the developing countries, too, receive their due and full share of the facilities and resources of the institutions proposed here for federation.

Affiliation Criteria

The essential element of the present plan is to start to identify internationally operated and staffed research institutions (mainly in scientific subjects) and to strengthen the international aspect of their program through an association with the UN. There is no dearth of institutions which are, to a lesser or larger degree, international, even though their original charters do not specify this. The idea would be to make them even more consciously so, by according them a UN charter if they satisfy certain specified criteria.

Such centers would have to possess the highest quality rating and an international faculty, staff and research fellows; they would also agree to spend a minimum portion (perhaps 15 to 25 percent) of their resources and their facilities for furthering the work of high-grade scholars from developing countries. (It is open whether a similar proportion should be fixed for the share of developed countries of different political complexions.) The UN may, when an expressed desire exists, select a certain number of presently existing or projected centers of excellence devoted to research and training, satisfying these criteria, to be linked together in a world federation, as I have suggested. (In the case of socialist countries with centrally planned economies, such centers may be presented by their respective governments for inclusion in the federation.)

To illustrate the working of one such center with respect to its international obligations, one may perhaps cite the example of the International Centre for Theoretical Physics at Trieste, Italy. This is not a typical case, but it does prove an example of a UN academic faculty in actual operation. The Centre was set up under the auspices of the International Atomic Energy Agency (IAEA) with the cooperation (and from 1970 equal participation) of the UNESCO. The Centre is devoted to imparting training for and conducting research in all disciplines of theoretical physics at the highest possible level. It draws its scientific faculty (visiting professors) and research fellows from, theoretically, ninety countries. (In practice, some fifty countries from the East, the West and the developing areas are represented.) The Centre maintains the highest possible standards of quality in research. But most crucially, 50 percent of its facilities and research positions are reserved for scientists from developing countries. The unique feature of the research places thus reserved is that the Centre offers dual appointments to senior and active theoretical physicists. Such appointments are held for a period from three to five years; the scholar is required to spend the bulk of his time — around nine months of the year — in his own country and the remaining three months in Trieste. In addition, the Centre has built up federation

links with research institutes in developing countries, on a cost-sharing basis, which afford mobility to staff and research fellows. At present there are some twenty such federated institutes in Eastern Europe, Latin America, the Middle East and Asia.

The proposed world federation of international institutes of advanced study would include centers like the International Centre for Theoretical Physics. Other institutes joining this federation could operate similar schemes of dual appointments and federation with institutions in developing (and developed) countries. There are a number of existing institutes of excellence which may wish to acquire the UN charter, and once the scheme is formulated, of course, there is not the slightest doubt there will be numerous others offering their facilities. To name just a few possibilities, there is the Asian Institute of Technology at Bangkok, for engineering studies; the Salk Institute at San Diego, for biological studies; the (proposed) European Institute of Technology in Geneva; the Institute of Oceanography at Woods Hole. A number of other institutes in the USSR, Great Britain, France and developing countries immediately spring to mind, which would doubtless welcome the opportunity to belong to such a federation – to widen their facilities to share staffs and visitors and be obligated thus to throw their door open to scholars of developing countries.

The action needed to carry out the project proposed here would be: 1) To make the idea widely known and accepted by a number of centers of excellence; 2) To define the criteria for a UN charter, on the lines proposed. For this one needs the meeting of a group of world scholars and those who run centers of excellence around the world. 3) Finally, to have the idea of according UN recognition to such institutes and the setting up of the world federation accepted at the General Assembly of the United Nations.

The UN would not be spending any vast sums on the proposed federation. The financing of the institutes would still come from the present sources, which fund them, as indeed would the basic governing of the institutes, except in regard to their international functions. However, the UN might create a small administrative cell within the organization to make possible contacts between the federating institutes and to ensure common policies and practices. Discussion within the Secretariat appears to show that these ideas would be very well received there. ■

15

Memorandum on Islamic Science Foundation

Islamic Science Foundation

1. This is a proposal for the creation of a Foundation, by Islamic countries, with the objective of promotion of science and technology, at an advanced level. The Foundation (working in conjunction with the Islamic Conference) would be sponsored by the Muslim countries, and operate within these, with an endowment fund of \$1,000 million and a projected annual income of around \$60-70 million. The Foundation will be *non-political, purely scientific, and run by eminent men of science and technology from the Muslim world.*

2. Need

No Muslim country, in the Middle East, in the Far East or Africa possesses high-level scientific and technological competence attaining to any international level in quality. The major reason is the persistent neglect by Governments and society in recent times in acquiring such competence. In relation to international norms (around 0.3% of economically active manpower engaged in higher scientific, medical and technological pursuits, with around 1% of GNP spent on these) the norms reached in the Islamic world are one-tenth of what one should expect for a modern society.

3. Objectives of the Foundation

It is suggested that a well-endowed Islamic Science Foundation be created with two objectives; building up of high-level scientific personnel and building up of scientific institutions. In pursuit of these objectives: a) The Foundation will create new communities of scientists in disciplines where none exist. It will strengthen those communities, which do exist. This will be done in a systematic manner, with the urgency of a crash program. b) The Foundation will help in building up and in strengthening institutions for advanced scientific research at the international level, both in pure and applied fields, relevant to the needs of Muslim countries and their development. The emphasis of the Foundation's work would lie in building up sciences to international standards of quality and attainment. Of the two objectives listed above, the building up of high-level scientific personnel will receive the higher priority in the first stages of the Foundation's work.

Presented at the Conference of Islamic Countries, Lahore, July 2, 1973.

4. Program

In pursuance of its twin objectives (a) of building up high-level scientific manpower in a systematic manner, and (b) of employing this manpower for advanced work for the betterment and strength of Islamic societies, the Foundation will pursue the following program.

a) *Building up of scientific communities*

i) Scholars will be sponsored by the Foundation to acquire knowledge of advanced sciences, wherever available, in areas where gaps exist and where there are no existing leaders of sciences. After their return to their countries, the Foundation will help them continue their work. Funds of the order of \$10 million would support some 4,000 scholars annually while they are receiving advanced training, and support around 1,000 scholars and the needed facilities on their return.

ii) Programs will be organized around existing scientific leaders in order to increase high-level scientific manpower. For this purpose, contracts will be awarded to university departments to strengthen their work in selected fields. Quality of the University faculties will be the criterion for the award of these contracts. Funds to the total of around \$15 million may be spent annually for these contracts.

iii) Contact of scholars from the Islamic world with the world scientific community. Existing science in Muslim countries is weak because of its isolation. There are no contacts between scholars in Muslim countries and the world scientific community, principally on account of distance. Science thrives on the interchange of ideas and on continuous criticism. In countries with no international scientific contacts, science ossifies and dies. The Foundation will endeavor to change this. This will entail frequent two-way visits of fellows and scholars, and holding of international symposia and conferences. Funds of the order of around \$5 million will subsidize some 3,000 visits a year of around two months' duration. This, spread over around ten sciences and over fifteen countries, is about twenty visits a year from any one country in any one science.

b) *Sponsoring of relevant applied research.* The Foundation may spend around \$25 million for the strengthening of existing and the creation of new research institutes on problems of development in the Middle East and the Islamic world. These new institutes of international level and standing would be devoted to research in problems of health, technology (including petroleum technology), agricultural techniques and water resources. These institutes may also become units of the United Nations University system in order to attain international standards of quality and achievement through contact with the international community. (A successful institute like the International Rice Research Institute in the Philippines costs about \$5-6 million to create, and about the same amount to run at an *international level*).

c) The foundation may spend \$5 million in making the general population of Islamic countries technologically and scientifically minded. This will be achieved through instruction using mass media, through scientific museums, libraries and exhibitions, and through the award of prizes for discoveries and inventions. An appreciation of science and technology by the masses is crucial if there is to be a real impact of science and technology.

d) The Foundation will help with the task of modernizing syllabi for science and technology at the high school as well as university level.

5. Functioning of the Foundation

a) The Foundation will be open to sponsorship by all Islamic countries which are members of the Islamic Conference.

b) The Foundation will have its headquarters at the seat of the Islamic Conference. In order to retain active and continuous contact with the research centers and projects it endows, it may set up subsidiary offices as well as employ scientific representatives, resident or at large.

c) The Board of Trustees of the Foundation, which will be responsible for liaison with the Governments, will consist of representatives of the Governments, preferably scientists. The endowment fund of the Foundation will be vested in the name of the Board of Trustees.

d) There will be an Executive Council of the Foundation, which will consist of scientists of eminence from the Muslim countries. The first Council and its Chairman (who will also be the Chief Executive of the Foundation) will be appointed by the Board of Trustees for a five-year term. This Council will decide on the Foundation's scientific policies, the expenditures of the funds, their disbursement and their administration. The work of the Foundation and the Executive Council will be free from political interference. The Board of Trustees, through the statutes, will be charged with the responsibility of ensuring this.

e) The Foundation will have the legal status of a registered non-profit making body and will have a tax-free status both in respects of its endowments as well as emoluments of its staff.

f) The Foundation will build up links with the United Nations, UNESCO and the United Nations University system, with the status of a Non-Governmental Organization (NGO).

6. Financing of the Foundation

a) It is envisaged that the sponsoring countries would pledge themselves to provide the endowment fund of \$1,000 million in four yearly installments.

b) The proportion of the endowment fund to be contributed by each sponsoring country will be a fixed fraction of the export earning of the country. The 1972 schedule of export earning for the Muslim countries is appended [in the original document]. In future years, these earnings are expected to increase.

However, even at the 1972 level of 25 billion dollars per year, a contribution of less than one percent per country per year would suffice to build up the initial endowment capital of one billion dollars over four years.

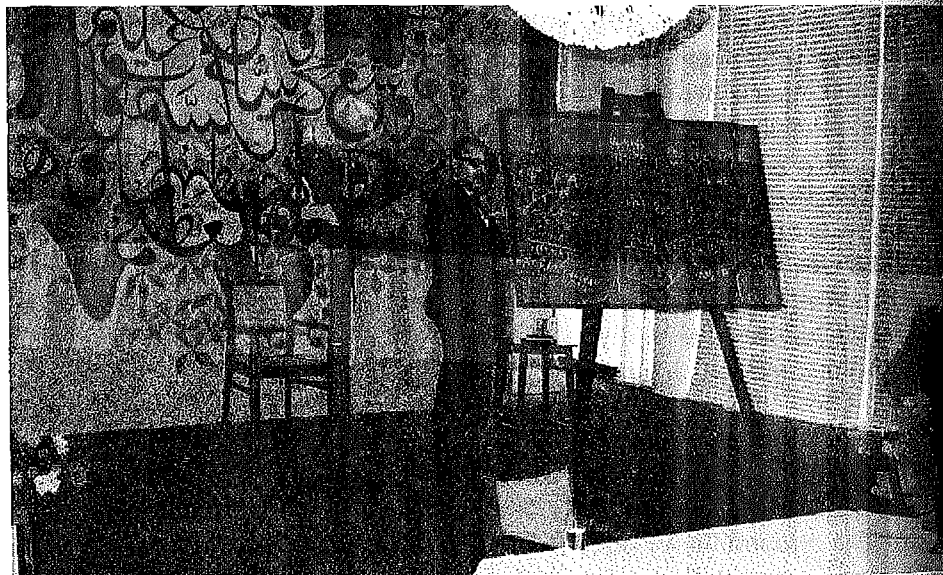
July 2, 1973

Note added in 1985

This memorandum was written in the economic climate of 1973, before the first rise in oil prices. If I were writing this today, I would not be content with one Ford-size Foundation. On standard norms, the Islamic world – individual countries, as well as collectively – needs and deserves fifty independent foundations for Science, Technology and Science Education. This is because in the twelve intervening years, the GNP of Islamic countries has risen many-fold. And let me say this emphatically. Even today, even after the recent drop in oil prices, we are not so poor as not to afford outlays on Sciences of an order, which the rest of the world routinely makes.

Regarding our collective responsibility towards the Ummah, on the Day of Reckoning – in this world and hereafter – nations, as well as individuals (bankers, financiers, merchants, ministers, industrialists, all of those designated as *matar fiha* in the Holy Book), will surely be questioned and judged on the uses they made of what Allah has bestowed on them.

“Our Lord, condemn us not if we forget or fall into error; our Lord, lay not on us a burden like that which You didst lay on those before us.”
(*Al-Qur'an*, 2: 286) ■



33. Salam lecturing at the Public Library, Lahore

16

The United Nations University

In the March 1970 issue of the *Bulletin*, I wrote about the creation of a world university. Since then, events have moved with rapidity, and it appears that a postgraduate international university, under UN auspices, is likely to start functioning, possibly in 1974. I am writing this note to bring the readers of the *Bulletin* up to date in respect to the progress of this project, hoping that the world academic community will take note and influence the shape of the university in the process of being created.

The idea of creating an international university under UN auspices was put forward formally by U Thant in September 1969, in the introduction to his annual report on the work of the United Nations. Between then and December 1972, the idea was sharpened and defined by panels of experts and discussed by the various legislative organs of the UN family, including the Economic and Social Council (ECOSOC), the UN Educational, Scientific and Cultural Organization (UNESCO), and the UN Institute for Training and Research (UNITAR). On December 11, 1972, the General Assembly of the United Nations adopted a resolution whose operative paragraphs read as follows.

The General Assembly

1. Decides to establish an international university under the auspices of the United Nations to be known as the United Nations University;
2. Decides that the United Nations University should be guided, inter-alia, by the following objectives and principles:
 - a. The concept of the University should be that of a system of academic institutions and not of an inter-governmental organization; [...]
 - c. Binding guarantees, under law, of academic freedom and autonomy should be written into the charter of the University;
 - d. Selection procedures should be established so as to ensure the highest intellectual and moral quality of the personnel of the University;
 - e. The structure of the University should consist of a programming and co-ordinating central organ and a decentralized system of affiliated institutions, integrated into the world university community, devoted to action-

oriented research into the pressing global problems of human survival, development and welfare that are the concern of the United Nations and its agencies, and to the post-graduate training of young scholars and research workers for the benefit of the world community;

f. The research program of the institutions of the University should include, among other matters, coexistence between peoples of differing cultures, tongues and social systems, peaceful relations between States and the maintenance of peace and security, human rights, economic and social change and development, the environment and the proper use of resources, basic scientific research and the application of the results of science and technology in the interests of development;

g. Capital costs and recurrent costs should be met from voluntary contributions for the University, made: i) directly by Governments or through the United Nations, the specialized agencies or the International Atomic Energy Agency; ii) by non-governmental sources including foundations, universities and individuals.

The University should also be authorized to receive assistance for its projects, particularly fellowships, from the United Nations, the specialized agencies, the International Atomic Energy Agency and other inter-governmental organizations; [...]

The General Assembly further requested the Secretary-General to establish a Founding Committee of twenty experts drawn from different disciplines and countries to draft the charter of the United Nations University.

The committee, chaired by Dr. Andrew Cordier of Columbia University, New York, has met in one session in New York held between March 27 and 30, 1973. It concluded its work in a second session held during June 1973 in Paris. The Secretary-General was also asked by the General Assembly to commence efforts for raising the necessary funds in order to permit the launching of the university at the earliest possible date.

As can be seen from the General Assembly resolution, structurally, the university is to be a decentralized system, consisting of postgraduate institutions in different parts of the world, undertaking, first, interdisciplinary studies of major global issues of concern to mankind and, second, advanced training and research in basic and applied sciences particularly with the needs of developing countries in view. The work of these units would be coordinated by a central programming and coordinating unit. In addition, the United Nations University system would endeavor to stimulate the thinking and efforts of existing institutions of higher learning in various parts of the world to the objectives of the United Nations charter and to link these efforts in a systematic way to the efforts of the United Nations family.

In his opening statement to the Founding Committee, Secretary-General Kurt Waldheim emphasized:

Dissemination of knowledge, exchange of academic personnel, and the generation of catalytic ideas would constitute the central functions of the University. Consequently, most of the scholars may be expected to participate in the network's activities in a rotational, rather than permanent basis. It is felt that the problem of the "brain drain" which afflicts many of the developing countries, will be at least partially alleviated when the scholars keep their positions at their national universities and research centres and visit units of the United Nations University periodically in a system of "dual appointments".

Since the United Nations is a very poorly endowed organization, mainly due to the parsimony of the big powers, and since the Secretary-General has been specifically requested to raise funds for the UN University system (outside of the UN regular budget), the response to his request from member States to make offers for the creation of units in their own countries is the crucial element in bringing the system into existence. Fortunately, a number of countries have expressed strong interest in sponsoring and financing units in different disciplines: Japan, Canada, Italy, Germany, France and Austria as well as a number of developing countries around the world.

There is need of national committees of scholars to be created in each country. These committees, in cooperation with their national UN representatives, could help in the definition and the realization of this great project.

Two major functions which such committees could perform at this stage are:

- 1) They could help to stimulate offers from their national governments regarding units of the proposed university to be located within their countries.
- 2) They could help in creating mechanisms to link effectively the national academic and university systems with the international system proposed. ▢



34. U. Thant



35. Andrew Cordier

17

A World Federation of Institutes of Advanced Study

A number of groups have been working independently towards the project of setting up one or more world universities. That this is of importance in the context of the international future of mankind goes without saying. That at least one university did not come into existence at the same time as the United Nations organization did in 1945 is something of which the world's academic community cannot feel proud. Recognizing this, at its twenty-fourth session, in 1969, the General Assembly of the United Nations adopted the resolution 2573 (XXIV) inviting the Secretary-General to undertake a comprehensive expert study on the feasibility of an international university. In introducing this widely sponsored resolution, it was stated that "the establishment of an international university would satisfy the aspirations which were becoming apparent in all parts of the world and it would fulfill an obvious need."

There are at least four reasons for this universal interest in the setting up of one or more international world universities:

1) *The idealistic reason – international understanding.* There is no instrument more potent in bringing an appreciation of different – at present national – points of view than the atmosphere of an international university.

2) *Global studies.* Within the context of such a university there is the possibility of growth of international studies on global subjects – like international development, international economies, global environment, disarmament and the like.

3) *Contacts of scholars.* Human knowledge transcends national boundaries. To a scholar interested even in his narrow specialty, there is nothing more valuable than the possibility of free contact with his peers from all countries. A well-constituted world university may resolve the present political difficulties in achieving such contacts.

4) *Access to specialized knowledge for scholars from developing countries.* In the past, when scholars and scientists have worried about international contacts, they have tended to feel concern about East and West contacts only.

First published in the *Journal of the National Science Council of Sri Lanka*, 1:7-17 (1973).

One tends to forget the needs for contact of students and scholars from developing countries with their peers from developed countries. Opportunities for such contacts do not exist – not for political reasons, but because of economic factors. A world university, representing East, West and the Third World, is less likely to forget the needs of these students and scholars and more likely to afford them access to academic, scientific and technical areas at present the exclusive preserve of the richer countries. The developing countries fully recognize that a truly international university – preferably under the UN auspices – is the one real guarantee for their scholars to receive their share – as of right – of the facilities and resources of the international institutions to be created.

In response to the General Assembly resolution a study has been carried out on behalf of the Secretary-General. This study suggests the setting up of a set of postgraduate international institutions within the United Nations family – to be called UN International Universities – with two objectives:

a) "To enable scholars from all parts of the world jointly to study, research and reflect on the principles, moral imperatives, objectives, purposes, perspectives and needs of the UN system in the light of its fundamental laws and developing accords, declarations, resolutions and programs."

b) "Secondly, to undertake a continuing and widely-based international scholarly effort of study and research, directed in consonance with Charter obligations towards social, economic and cultural progress through co-operation among nations and peoples. The universities would achieve these ends through emphasizing ... relevant international studies, largely inter-disciplinary, of wide and generally global significance."

It is clear that the objectives of this particular response to the General Assembly resolution are limited to the special global studies related to global problems. This is not going to be a traditional university pursuing the traditional range of subjects, but a specialized institute or set of institutes.

Commendable as this response is, it falls short of the aspirations of at least two of the communities, which have supported world university projects. By and large both these communities have had in mind the traditional range of academic disciplines, in addition to global studies. The two communities are:

1) Academic scholars and scientists in East and West who desire in their traditional disciplines more contacts with each other.

2) Developing countries who look upon the world university idea as the one way by which they can secure entry for their students and scholars into the privileged intellectual, scientific and technological club on terms of equality. Notwithstanding the fact that no stated bar operates against anyone from a developing country pursuing advanced studies and research at any of the world's great institutes, in practice the economic and other factors do operate in such a

manner that at least the scientific and technological gap between the poor and the rich countries grows ever wider. The developing countries look upon the world university project as a means to bridge this gap.

From this it would seem that nothing short of one or more full-fledged world universities in traditional disciplines – at least for post-graduate scientific and technological studies – will satisfy these two groups.

Unfortunately, to develop full-fledged universities – and particularly under UN sponsorships – is not all that easy. One does not have to recount the difficulties, which are likely to be met. Since the sums of money involved are large, it is out of the question that the United Nations Organization – even with the generous support of the World Bank – could finance such a venture. It is also unclear if one could get a number of the richer countries passionately interested in a project of this type and ready to back it. There are too many casualties among proposed international or regional institutions in the academic field already not to give one great hopes of success, unless one proceeds in a gradual manner. Further, the choice of location of such a world university in one country in preference to another will always present difficulties. Even the choice of faculties to develop first is not going to be all that plain sailing.

One way to circumvent the difficulty of creating new institutes, and yet to achieve at least partly some of the objectives listed above, is to take advantage of existing centers of excellence and quality which would like to discharge international functions and to link such centers with the UN institutions for global studies proposed by the Secretary-General, the whole making up the beginning of a world university.

This note then is concerned with a world university idea emerging gradually from an amalgam of the UN institutes together with existing centers of advanced studies linked in a federation. In the first instance the emphasis is on post-graduate research and training for research. Later development of the ideas may envisage undergraduate studies and the corresponding institutions.

Let us consider the various stages of the post-graduate plan. The important point we wish to make is that every part of the plan has merits of its own, irrespective of whether the later stages follow or not. The first stage is the identification of such existing institutions, which already operate substantial international programs. There is around the world no dearth of institutions of quality which are to a lesser or larger degree international in character, even though their original charters do not specify this. The idea would be to make them even more consciously so. The hope is that a voluntary federation would help in this: at the least in defining norms and making it possible to share experience; at the best in raising new funds for the international operation. As a

second part of the plan, and if this federation so chooses, a UN charter could be accepted and a formal link established with the UN Institution on Global Problems proposed by the Secretary-General. The centers constituting the federation and conveying traditional disciplines together with the Secretary-General's UN University on Global Problems, would make a complementary whole – the beginning of a world university.

Such centers as should belong to the proposed federation must satisfy certain criteria. For example, such centers must possess the highest rating of quality; they must possess – to a lesser or greater degree – an international faculty of staff and research fellows; they must agree to spend a minimum proportion (to be fixed, perhaps between 15-25%) of their resources and their facilities towards furthering the work of high-grade scholars from developing countries.

To illustrate the working of one such center, one may perhaps cite the example of the International Centre for Theoretical Physics at Trieste, Italy. This case is not typical because the institute is financed and run by two of the United Nations Agencies, but it does provide an example of the type of international academic faculty in actual operation. The Centre was set up under the auspices of the International Atomic Energy Agency (IAEA) with the co-operation (and from 1970 equal participation) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The Centre is devoted to imparting training for and conducting research in all disciplines of theoretical physics at the highest level. It draws its scientific faculty (consisting mainly of visitors) and research fellows from (theoretically one hundred but in practice) some fifty countries of the East, West and the third world. Some 50% of its facilities and junior and senior research positions are reserved for scientists from developing countries. A unique feature is that the Centre offers dual appointments to active senior theoretical physicists from developing countries. Such appointments are held for periods of three to five years; the scholar spends the bulk of his time – about nine months of the year – in his own country, and the remaining three months of every year in Trieste. In addition, the Centre has built up federation links with some twenty research institutes in various countries – on a cost-sharing basis – which afford mobility of their staffs and research fellows. On the East-West co-operation side, as a UN-sponsored organization, the Centre plays an absolutely unique role: it is one of the few places in the world where physicists in subjects as sensitive as plasma research from the East and West meet regularly and for prolonged period (quarters or years) and with no national pride or sensitivities inhibiting scientific concourse.

The proposed World Federation of International Institutes of Advanced Study would include centers with already a large international program or desirous of starting one. The institutes which would join this federation may operate schemes of dual appointments and federation with corresponding centers both in developed and developing countries. From informal contacts one knows

that a number of institutes in the USA, the USSR, Great Britain, France and other countries are extremely desirous of widening their faculties internationally to share staffs and visitors with others in the same disciplines and, through the strength given to their international programs by the fact of belonging to such a federation, be obliged to throw their doors even more widely open to scholars from developing countries.

Why should a federation be created of institutes in diverse subjects? What advantages could come to the members of the proposed federation? Should it be independent institutes as well as institutes within national universities which should be invited to join? What about the financing of the international programs? And the links to the UN family?

In answering these questions, one has to ask if the federation could become stronger in any way in carrying out the international aspects of its programs than any one of its component unit. Would, for example, the Trieste Centre get any benefit by being federated in a sort of loose link with the Institute for Advanced Study at Princeton, or the Salk Institute for Biological Studies?

In our opinion, the answer to the last question is an affirmative "yes". The fact that a federation exists is likely to have important repercussions:

- 1) To get the general idea of international staffs and international use of facilities of scientific institutes accepted in a more "official" manner by the governing bodies of the institutes.

- 2) To secure a mobility of high-grade scientific personnel. Hopefully, there may emerge a UN Laissez Passer for academic personnel to travel freely, at least between the federating institutes, if the UN did not get involved with the federation idea.

- 3) A commitment in respect of scholars from developing countries: a federation to which a fair number of reputable institutions belong would go much further in organizing and getting accepted common standards. The committing of a certain percentage of resources to helping scholars from developing countries, and to scholars from countries with different political systems, is a new idea. Many institutes do set aside certain sums but there is no coherent policy about this. We are hoping that belonging to a federation would provide a visibility to these efforts and a better focus.

- 4) If we envisage that institutes from developing countries would also belong to such a federation, these institutes will in many cases have to raise their standards in order to qualify to join. This type of pressure would be an excellent tonic for them, and make the tasks of those running these institutes vis-à-vis their own governing councils – and their Governments – somewhat easier.

- 5) In respect of the question raised, whether it should be independent institutes which should federate or those located within universities, one should keep an open mind. In every case the permission of the governing bodies of the

institutes would be needed. I believe this is easier for independent institutions. For the present we may envisage only such institutes being invited, but the matter should be dealt with pragmatically.

6) The question of financing international programs is a difficult one. It is definitely envisaged that in the first instance the members of the federation would find funds from their own sources for this. Later, collective action may bring extra funding from outside – even from UN sources.

7) A first list of possible independent or semi-independent institutes which may consider forming initial memberships of the federation is suggested ... It is suggested that a preliminary meeting of Directors of these institutes be held to gain acceptance of the ideas in this note.

Note added in November 1972:

This memorandum was circulated in 1970 in a mimeographed form. The late Professor Arne Tiselius, President of the Nobel Foundation took up the ideas and at two Serbelloni meetings held during 1971 and early 1972, the idea of an International Federation of Institutes of Advanced Study was hammered out.

This Federation, consisting at present of twenty-four Institutes, was inaugurated at a meeting at Trieste during October 1972. Its offices are located in the Nobel Foundation House, Stockholm. Its Chairman is Nils Ståhle and its Secretary is Sam Nisson. □

18

Ideals and Realities

The short-term crisis the world faces is simply this. The developing world – some nine-tenths of humanity – is bankrupt. We, the poor, owe the rich – one-tenth of mankind – some \$50 billion. The poorest amongst us cannot even pay the interest on the money we borrowed, much less find the \$10 billion we collectively need to import ten million tons of cereals every year to feed ourselves. My own country, Pakistan, owes some \$6 billion, which is roughly equal to Pakistan's gross national product for one year or roughly equal to its export earnings for six years. Recently, London's prestigious *Economist* magazine starkly said, "The poorest among the poor who can neither borrow more nor draw on reserves will cut on their imports – their people will simply starve."

But this short-term crisis is only part of a longer-term crisis. Our world is terribly unbalanced in income and in consumption. At least three-quarters of the world's income, three-quarters of its investment, its services and almost all of the world's research are concentrated in the hands of one-quarter of its people. This one-quarter consumes 78 percent of the world's minerals, and for armaments alone, as much as the rest of the world combined. In 1970, the world's richest one billion people earned an income of \$3,000 per person per year; the world's poorest one billion, no more than \$100 each. And the awful part of it is that there is absolutely nothing in sight – no mechanism whatsoever – which can stop this disparity.

Development in the traditional pattern, the market economics, is expected to increase the \$100 per capita of the poor to \$103 by 1980, while the \$3,000

First published in *The Bulletin of the Atomic Scientists*, September 1976, pp. 9-15. This article is based, in part, on a speech Dr. Salam presented in 1975 to students at the University of Stockholm. A special session of the UN General Assembly had been convened in August and September 1975 to discuss the global crisis of the continuing and near-permanent disparity between the rich and the desperately poor – and the demand of the poor nations for a new international economic order – and Dr. Salam wrote this personal note for the Swedish students just after the session concluded. In it, he discusses – from the point of view of the developing countries – the crisis which led to the UN session

earned by the rich will increase to \$4,000; an increase of \$3 for the world's poorest and \$1,000 for the world's richest during the entire decade.

No wonder the poor nations consider visions of any growth and development through the traditional economic system a vicious fraud. This is the system which in the last twenty years created liquidity and credits of \$120 billion, but allocated just five percent of these to the poor nations. This is the system which pays \$200 billion for world commodities, but only one-sixth of this reaches the primary producer himself; the rest, five-sixths, goes to the distributor and the middleman in the rich nations. This is the system which gave \$7 billion in aid last year to the poor but took away almost exactly the same amount from the poor in depressed commodity prices. No wonder they are demanding in Omar Khayyam's words:

Ah, Love! Could thou and I with Fate conspire,
To grasp this sorry Scheme of Things entire,
Would we not shatter it to bits – and then
Re-mould it nearer to the Heart's Desire!

Over the past three to four years, some of the brighter young economists of the Third World countries, Brazil, Mexico, Algeria, and Pakistan, as well as some of the most distinguished figures in world economics, have been groping toward a new synthesis of development and outer limits of growth. I am ashamed for my own profession, physics, for there were no scientists or technologists associated with this team. It is this new synthesis – embodied in the so-called Cocoyoc and Rio Declarations – which formed the basis of the Resolution on a Declaration on Establishment of a New International Economic Order that was adopted in 1974 by the sixth special session of the UN Assembly. The 1975 special session of the Assembly was convened to put some teeth into the Charter of Economic Rights promulgated by the UN Assembly in 1974.

Among the poor these declarations have been likened to the great declarations of "The Rights of Man" in the 18th century by Tom Paine and the Communist Manifesto of the 19th century. What the establishments in the richer countries really think of the new International Economic Order is hard to fathom. The reaction in 1974 is probably typified by the words of one of the delegates from the richer nations to the United Nations referred to the "shadow world of rhetoric" and to "the drawback of so many short-lived resolutions, each longer than the last, one a repetition of the other, virtually unreadable." In 1975, though the response was still not outright commitment, Dr. Kissinger did present to the Assembly, on behalf of the richer nations, a welcome package of cooperative funds, joint institutes and aid initiatives. What is needed, however, is not just that the foreign and finance ministries of the developed countries should respond to the demands of the poor; but that the intellectuals and the general public should become aware of these demands and truly comprehend them.

In this spirit, I shall try to convey to you how a humble natural scientist from a developing country views the global crisis of the disparity between the rich and poor.

To understand the psychological thinking of the poorer nations, you must understand how recent this disparity is in our view. It is good to recall that three centuries ago, around the year 1660, two of the greatest monuments of modern history were erected, one in the West and one in the East: St. Paul's Cathedral in London and the Taj Mahal in Agra. Between them, the two symbolize, perhaps better than words can describe, the comparative level of architectural technology, the comparative level of craftsmanship and the comparative level of affluence and sophistication the two cultures had attained at that epoch of history.

But about the same time there was also created – and this time only in the West – a third monument, a monument still greater in its eventual import for humanity. This was Newton's *Principia*, published in 1687. Newton's work had no counterpart in the India of the Mughals. I would like to describe the fate of the technology which built the Taj Mahal when it came into contact with the culture and technology symbolized by the *Principia* of Newton.

The first impact came in 1757. Some one hundred years after the building of the Taj Mahal, the superior firepower of Robert Clive's small arms had inflicted a humiliating defeat on the descendants of Shah Jahan. A hundred years later still – in 1857 – the last of the Mughals had been forced to relinquish the Crown of Delhi to Queen Victoria. With him there passed away not only an empire, but also a whole tradition in art, technology, culture and learning. By 1857, English had supplanted Persian as the language of Indian state and learning. Shakespeare and Milton had replaced the love lyrics of Hafiz and Omar Khayyam in school curricula, the medical canons of Avicenna had been forgotten and the art of muslin making in Dhaka had been destroyed, making way for the cotton prints of Lancashire.

The next one hundred years of India's history were a chronicle of a more subtly benevolent exploitation. I shall not speak of this, but only of the scientific and technological milieu I was brought up in as a young man in British India. The British set up something like thirty-one liberal high schools and arts colleges in what is now Pakistan but, for a population then approaching forty million people, just one college of engineering and one college of agriculture. The results of these policies could have been foreseen. The chemical revolution of fertilizers and pesticides in agriculture touched us not. The manufacturing crafts went into complete oblivion. Even a steel plough had to be imported from England. It was in this milieu that I started research and teaching in modern physics some twenty-five years ago at Lahore, in the University of the Punjab.

Pakistan had then just won its independence after one hundred years of British rule. We then had a per capita income of \$80 a year, a literacy rate of 20 percent, a population growing at 3 percent a year and an irrigation system for agriculture which was breaking down. There was no social security and there was high child mortality; only five children out of twelve lived beyond one year. A child, a male child, was the only social security for old age one could budget for, making high birth rate imperative.

Pakistan, very willingly, agreed to become part of the free world economic bloc. We were relieved of worries of needing to grow more food for an increasing population. The US surpluses of wheat, under PL 480, gratefully came, at first in such abundance that one of our finance ministers spoke of curtailing wheat cropping by law in Pakistan to encourage tobacco growing instead. We imported highly talented development planners from Harvard University. They told us we did not need to put up a steel industry; we could buy any amount from Pittsburgh. We leased out our oil imports and even the distribution of petroleum products within the country to multinationals who conducted, in that age of oil surpluses, a half-hearted search for it.

Pakistan was thus a classic case of a post-colonial economy; political tutelage became economic tutelage. In the scheme of things, we were to provide cheap commodities – principally jute, tea, cotton, raw unprocessed leather. It was in 1956 that I remember hearing for the first time of the scandal of commodity prices – of a continuous downward trend in the prices of what we produced while the industrial prices of goods we imported went inexorably up as a consequence of the welfare and security policies the developed countries had instituted within their own societies. All this was called market economics. When we did build up manufacturing industries with expensively imported machinery (for example, for the production of cotton cloth), stiff tariff barriers were raised against these imports from us. With our cheaper labor, we were accused of unfair practices.

Of indigenous science and technology, or indeed of any technological manpower development, there was neither need nor appreciation nor any role for it. Any technology we needed, we bought. It came hedged with all types of restrictions. For example, no product which used this technology could be exported. And in any case, not all technology was for sale. Pakistan, for example, could not buy the technology of penicillin manufacture in 1955. My brother, together with a few other young chemists from Pakistan, reinvented the process, producing, as a result of their inexperience, penicillin at sixteen times the world price.

In the early 1950s, I looked upon my future in contributing to Pakistan's advance in technology and development as being non-existent. I could help my country in only one way, as a good teacher. I could produce more physicists, who for lack of any industry, would either become teachers themselves or leave the country.

But soon it became clear to me that even this role, that of a good teacher, would increasingly become impossible for me to maintain. In that extreme isolation at Lahore, where no physics literature ever penetrated, with no international contacts whatsoever, and with no other theoretical physicists around in the whole country, I was a total misfit. I knew that all alone I had no hope of changing the value of science and technology in Pakistan. There was but one recourse for me and that was to become engaged in the international scientific community.

My first opportunity to play a minor role in science and international affairs came in 1955 with the Atoms for Peace Conference held in Geneva. This was the first scientific conference held under UN auspices; the first conference at which the then existing secrecy between the East and West regarding nuclear fission, even over such information as neutron scattering cross-sections, was partly lifted. Atomic plenty – energy, isotope applications, new and revolutionary genetic varieties of crops – for the world was promised.

This was my first introduction to the United Nations. I remember entering that holy edifice in New York in June 1955 and falling in love with all that the organization represented – the Family of Man, in all its hues, its diversity, brought together for Peace and Betterment. It seemed to me then that any ideas I had of helping physics in Pakistan and in the developing countries must be implemented through the United Nations. I did not realize then how weak an organization it was, how fragile, and how frustrating in its inaction. My first decade in the world of science and international affairs, albeit in a very humble way, was thus a decade of innocence and hope; the second decade was to be one of growing frustration and a feeling of the hopelessness of it all.

My first disenchantment with the establishments representing their countries in the United Nations came in 1962 when Dag Hammarskjöld called for a conference to be held on science and technology. He had a vision of transforming the developing world through science and technology. I had the privilege of a long interview with Dag Hammarskjöld – the only time I met him – during which he shared with me his semi-mystical reverence for what science and technology could achieve for the poor if applied meaningfully.

Dag Hammarskjöld clearly recognized that what was needed first and foremost was investment, even if relevant technology was available. Much more than even the leaders of the developing world, he recognized that it was important to establish an indigenous scientific capacity in developing countries for research and development. This was needed, at the very least, to achieve an awareness of the significant developments of world science and technology – an awareness that would enable a country to select and negotiate the purchase and ensure the effective assimilation of the technology which its economic and social objective required.

Dag Hammarskjöld recognized that it is not just know-how which the developing countries need; it is also the *know-why* if technological development was to be a graft which should take in the poorer world.

The conference proposed by Dag Hammarskjöld was held in 1963, unfortunately after his tragic death. We, from the developing countries, proposed the creation of a World Science and Technology Agency – a technical development authority – backed by an international bank for technological development. Besides strengthening indigenous science in developing countries, the authority would act as a planning and programming body which would carry out feasibility studies, devise programs and arrange their implementation. Being a UN organization it would associate with its work and give maturity to local scientific and technological organizations and talent, giving them training and intimate knowledge of the complex new techniques. Its very existence would have emphasized what the planning economist so often forgets: that the modern world and its problems are a creation of modern science and technology.

We proposed this; we lobbied for this. But we met with a complete blank wall of incomprehension, or worse, on the part of the delegates from the industrialized countries. By and large they opposed the idea of any such thing as a World Science and Technology Agency. It seemed they preferred that the scientific and technological effort of the United Nations remain weak and fragmented within the system. There appeared to be no desire on the part of the delegates from the industrialized nations to share technology with the developing world, except through the existing system of licensing.

The net legacy of this conference was the creation of an eighteen-man Advisory Committee on Science and Technology. We met twice a year for eleven years. After eleven years labor, we have recommended yet another UN Conference on Science and Technology, which is to be held in 1978, to meet and create the same World Science and Technology Development Agency we proposed fifteen years ago. However, this time we will probably get it, because Dr. Kissinger gave the proposed conference his blessing in 1975.

I had met the same blank wall, the same incomprehension, when the idea of a theoretical physics center was first presented to the International Atomic Energy Agency (IAEA). The idea of the creation of such a center was particularly incomprehensible to some of the countries where theoretical physics flourishes. In fact, one delegate went so far as to say: "Theoretical physics is the Rolls Royce of sciences. What the developing countries want is nothing more than bullock carts." To him a community of twenty-five physicists and fifteen mathematicians trained at a high level for a country, say, like Pakistan was simply forty men wasted. That these men would be responsible for all norms and all standards in the entire spectrum of education in physics and mathematics in Pakistan was totally irrelevant. He was an economist, who could fully

understand that we needed more high-level economists; but physicists and mathematicians – that was a wasteful luxury.

In 1964, when the IAEA did agree to the physics center, its Board voted us a sum of \$55,000 to create the International Centre for Theoretical Physics. Fortunately, the government of Italy came through with an annual grant of \$350,000 and the center was set up in Trieste, Italy, and started operating in 1964. It is now co-sponsored by IAEA and UNESCO, together with the UN Development Program, and both now contribute about \$250,000 each. The Centre continues to receive the annual grant from the Italian government, and it also received a grant of \$100,000 from the Swedish International Development Agency.

During the twelve years of its existence the Centre has received some 6,000 senior physicists from ninety countries – 4,000 of them from sixty-five developing countries. It has truly created something of a revolution so far as the studies of physics are concerned in the developing world. Over the years it has tended more and more to emphasize technology transfer in physics. In this, we have particularly been helped by a Solid State Committee headed by J. Ziman of Bristol and S. Lundqvist of Chalmers in Gothenburg. Last year we inaugurated the first three-month course on the physics of oceans and atmosphere, which was attended by some sixty senior physicists, meteorologists and ocean scientists from some thirty developing countries.

The Centre, however, still remains unique – the one, isolated center of its kind in the entire spectrum of advanced scientific knowledge within the United Nations family.

It was in 1963 though that the disillusionment with the existing international order came fast, the beginning also of my second decade in the world of science and international affairs. President Kennedy, who, rightly or wrongly, symbolized liberal aspirations – and world development – was assassinated. Then, around 1968, came the student revolts and the realization that the environment was being wrecked.

I felt then, and still feel, that the developing world lost a great moment, lost a great potential alliance, a great potential source of strength when the protesting energy of world youth concentrated on the one issue of environment and did not espouse at the same time the more embracing cause of world development.

In between these years came the repeated failures of the UN Conference on Trade and Development (UNCTAD) proposals to redress the relatively ever-falling commodity prices. It is good to be reminded today that the price of petroleum fell decisively between 1950 and 1970 – down to \$1 a barrel, stimulating a growth in energy use of between 6 percent to 11 percent.

The reception of UNCTAD's proposals – its fervent appeals for some stability and indexing of commodity prices – were received with derisory scorn.

For example, the influential London *Economist* stated in its August 30, 1975, issue on the eve of a UN conference: "The notion that the price of each commodity can be tied, not to the demand for it, but to the average rise in the price of manufactured goods, is a proposal to try to repeal, by some conference, the Laws of Supply and Demand. The industrial countries should simply refuse any concessions to this proposal."

And this in a year which saw the index of manufactures prices go up to one hundred and forty, while the commodity price index hovered around one hundred and fourteen. Thus, in this one year alone, the poor have subsidized the welfare economies of the rich to the extent of 26 percent of their earnings.

In 1972 came the great UN Conference on the Human Environment in Stockholm. It was significant not just for pinpointing that the environment was being wrecked and that some countries were contributing more than their fair share toward wrecking it. Even more important, it thrust into prominence the interdependence of the human community in solving the issues raised.

In 1972 came also the Club of Rome report *The Limits to Growth*, with its thesis that world resources are finite and simply could not sustain infinite growth of industrialized economies. It is not well known that the poor countries had received a sharp reminder of this – as early as mid-1972 – in the form of a precipitous doubling of the price of wheat. This happened because of a crop failure in the USSR which forced the Soviets to buy thirty million tons of grain, nearly exhausting the world grain reserves.

This was one of the contributory causes of the threefold increases in oil prices, followed by yet another doubling of grain prices. Add to this the waning of the resource transfers of foreign aid programs (the one collective commitment of the western countries) and you can understand the origins of the short-term crisis – the financial bankruptcy of the desperately poor nations.

Speaking of foreign aid, the seventeen richest nations allocated 0.3 percent of their gross national products to overseas development in 1974, compared with 0.52 percent in 1960. While Sweden generously earmarked 0.72 percent, the United Kingdom and the United States provided 0.30 percent and 0.25 percent, respectively. The World Bank estimates that by 1980 the average of the seventeen countries will be 0.28 percent and the United States, 0.18 percent. Contrast this with the US contribution of 2.79 percent of GNP at the beginning of the Marshall Plan.

Ministries in rich countries usually dismiss as unrealistic the United Nations' target of allocating 0.7 percent of their GNP to aid. Yet this target could probably be reached in the second half of this decade if the rich nations merely devoted 2 percent of the increased wealth – the \$1,000 per capita growth I mentioned above – which is expected to accrue in these nations in the next few years.

Realizing these stark facts, and realizing that the developed world was unlikely to produce a Messiah – or even a Keynes, who would preach social justice between nation and nation – the developing countries decided in 1974 to use the forum of the United Nations for calling for a New International Economic Order.

Given that the developed countries, by and large, have shown remarkable reluctance to initiate and support change, and that they have derived much of their wealth from cheap resources and raw materials of the developing countries, and that they still refuse to give access to their markets to the Third World, the struggle of the Third World is now for economic liberation. The Third World wants greater equality of opportunity and the right to sit around the bargaining tables as equals with a redistribution of future growth opportunities.

The UN resolution on the New International Economic Order calls for:

- a commitment from mankind for the banishment of poverty and prevailing disparities;
- a just and equitable relationship between prices of raw materials and manufactured goods;
- access to the achievements of modern science and technology;
- an end to wasteful consumption, particularly in respect to food and expenditure on armaments.

Keeping in mind the above “demands” of the Third World, let us consider food and military expenditures in somewhat greater detail.

Food. In November 1974, the United Nations convened a conference in Rome on food. This conference adopted the following declaration: “Within a decade no child will go to bed hungry and no family will fear for its next day’s bread and no human being’s future will be stunted by malnutrition.” To achieve this target a World Food Council was set up, with the minimum target of distributing ten million tons of grain a year as food aid, and of achieving average 3.6 percent increases per year in food production by poor countries through an international provision of agricultural inputs.

On June 29, 1975, the *London Times* reported that: “The World Food Council ended its inaugural meeting here in Rome at 2:00 a.m. yesterday. It was saved from being an obvious farce and a failure only by some quick face-saving footwork by western diplomats. France, Germany, and Italy have so far refused to endorse an increase in EEC’s food aid from 1.3 million tons to 1.6 million tons. This was bitterly attacked in Rome, not the least by the United Kingdom which threatened to increase its own bilateral aid if the insensitivity of its partners continued. The commitment to ten million tons – even though well short of food aid levels of 1960 – has still not been reached.”

Is there a real absolute overall shortage of food in the world, which makes the contribution of this ten million tons impossible – with the inevitability of starvation in poor countries? The answer is NO.

It should be emphasized again and again that the grain is physically available. It is simply being consumed by well fed people. Since 1965, the richer nations have added three hundred and fifty pounds per head to their annual diets, largely in the form of beef and poultry. This was stimulated by a special pricing policy at a time when US surpluses of food grains were running in excess of world demand by some sixty million tons a year, in spite of a curtailment in area cropped – by one-half. This is very nearly the equivalent of an Indian's total diet for a whole year.

Few will maintain that the industrialized countries were undernourished in 1965. A cut in consumption, for example, the suggested equivalent of one hamburger a week, could provide all the grain needed to support a population as large as one-third of the Indian subcontinent.

Armaments and arms reduction. In 1973, the world military expenditure came to \$245 billion. This sum is one hundred and sixty-three times greater than that spent on international cooperation for peace and development throughout the UN system (which stands at approximately \$1.5 billion, excluding the World Bank). The superpowers spent 50 percent of the \$245 billion while another 30 percent was spent by military alliances. The share of the Third World also, unfortunately, increased between 1955 to 1975 from 6 percent to 17 percent; we are not entirely blameless.

The world's military expenditures are now greater than the GNP of all of Africa and all of South Asia. During the two decades, the 1960s and 1970s, the total military expenditure was \$4,000 billion, which is greater than all goods and services produced by all mankind in one year.

When we consider the situation with materials and men, the situation regarding military expenditures appears even grimmer.

Close to 7 percent of all raw materials in the richer countries are consumed by the armament industry. This includes oil, iron, tin, zinc, copper and bauxite.

It is estimated that about fifty million people are employed for military purposes in armed forces and defense activities. Close to half a million scientists and engineers – almost half of the world's scientific and technological manpower – are devoted to military research and development, costing between \$20 and \$25 billion. These sums represent 40 percent of all public and private research and development expenditures appropriated by mankind.

The situation is clear. It is not the poor countries who jeopardize the global balances; it is the rich and their rivalries and their desire to hold monopoly military power.

The demand for a New International Economic Order is a demand of a basic minimum standard of living and of economic security for all citizens; a deliberate policy of development and redistribution to achieve this. On the national level, the achievement of social and economic goals is not left entirely to individual effort and initiative, but is prompted actively by the combined efforts of the entire community. On the international level, the aspirations of the nations of the world in the social and economic sphere should be made easier to achieve by a concentrated effort of the world community – by the Family of Man, acting as a whole. ▮

36. Co-recipients of the 1979 Nobel Prize for Physics



Sheldon Glashow



Abdus Salam



Steven Weinberg

19

Nobel Prize for Physics 1979:
Excerpts from the Nobel Lecture,
Award, and Remarks at the Nobel Banquet

*Excerpts from Professor Abdus Salam's Nobel Lecture:
Gauge Unification of Fundamental Forces,
December 8, 1979*

In June 1938, Sir George Thomson, then Professor of Physics at Imperial College, London, delivered his 1937 Nobel Lecture. Speaking of Alfred Nobel, he said: "The idealism which permeated his character led him to ... [being] as much concerned with helping science as a whole, as individual scientists. ... The Swedish people under the leadership of the Royal Family and through the medium of the Royal Academy of Sciences have made Nobel Prizes one of the chief causes of the growth of the prestige of science in the eyes of the world. ... As a recipient of Nobel's generosity, I owe sincerest thanks to them as well as to him."

I am sure I am echoing my colleagues' feelings as well as my own, in reinforcing what Sir George Thomson said – in respect to Nobel's generosity and its influence on the growth of the prestige of science. Nowhere is this more true than in the developing world. And it is in this context that I have been encouraged by the Permanent Secretary of the Academy – Professor Carl Gustaf Bernhard – to say a few words before I turn to the scientific part of my lecture.

Scientific thought and its creation is the common and shared heritage of mankind. In this respect, the history of science, like the history of all civilization, has gone through cycles. Perhaps I can illustrate this with an actual example.

Seven hundred and sixty years ago, a young Scotsman left his native glens to travel south to Toledo in Spain. His name was Michael, his goal to live and work at the once Arab Universities of Toledo and Cordova, where the greatest of Jewish scholars, Musa ibn Maimun [Maimonides], had taught a generation before. Michael reached Toledo in 1217 AD. Once in Toledo, Michael formed the ambitious project of introducing Aristotle to Latin Europe, translating not from the original Greek, which he knew not, but from the Arabic translation then taught in Spain. From Toledo, Michael traveled to Sicily, to the Court of Emperor Frederick II. Visiting the medical school at Salerno, chartered by Frederick in 1231, Michael met the Danish physician, Henrik Harpestraeng – later to become Court Physician of Eric IV Waldemarsson. Henrik had come to Salerno to compose his treatise on blood-letting and surgery. Henrik's sources

were the medical canons of the great clinicians of Islam, Al-Razi and Avicenna which only Michael the Scot could translate for him.

Toledo's and Salerno's schools, representing as they did the finest synthesis of Arabic, Greek, Latin, and Hebrew scholarship, were some of the most memorable of international assays in scientific collaboration. To Toledo and Salerno came scholars not only from the rich countries of the East, like Syria, Egypt, Iran and Afghanistan, but also from developing lands of the West like Scotland and Scandinavia. Then, as now, there were obstacles to this international scientific concourse, with an economic and intellectual disparity between different parts of the world. Men like Michael the Scot or Henrik Harpestraeng were singularities. They did not represent any flourishing schools of research in their own countries. [...]

After 1350, however the developing world loses out except for the occasional flash of scientific work, like that of Ulugh Beg – the grandson of Timurlane, in Samargand in 1400 AD; or of Maharaja Jai Singh of Jaipur in 1720 – who corrected the serious errors of the then Western tables of eclipses of the sun and the moon by as much as six minutes of arc. As it was, Jai Singh's techniques were surpassed soon after with the development of the telescope in Europe. As a contemporary Indian chronicler wrote: "With him on the funeral pyre, expired also all science in the East." And this brings us to this century when the cycle begun by Michael the Scot turns full circle, and it is we in the developing world who turn westward for science. As Al-Kindi wrote 1100 years ago: "It is fitting then for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us. For him who scales the truth there is nothing of higher value than truth itself; it never cheapens nor abases him."

Ladies and Gentlemen, it is in the spirit of Al-Kindi that I start my lecture with a sincere expression of gratitude to the modern equivalents of the Universities of Toledo and Cordova, which I have been privileged to be associated with – Cambridge, Imperial College, and the Centre at Trieste.

I. Fundamental Particles, Fundamental Forces, and Gauge Unification

The Nobel lectures this year are concerned with a set of ideas relevant to the gauge unification of the electromagnetic force with the weak nuclear force. These lectures, coincide nearly with the 100th anniversary of the death of Maxwell, with whom the first unification of forces (electric with the magnetic) matured and with whom gauge theories originated. They also nearly coincide with the 100th anniversary of the birth of Einstein – the man who gave us the vision of an ultimate unification of all forces.

The ideas of today started more than twenty years ago, as gleams in several theoretical eyes. They were brought to predictive maturity over a decade back. And they started to receive experimental confirmation some six years ago.

In some senses then, our story has a fairly long background in the past. In this lecture I wish to examine some of the theoretical gleams of today and ask the question if these may be the ideas to watch for maturity twenty years from now.

From time immemorial, man has desired to comprehend the complexity of nature in terms of as few elementary concepts as possible. Among his quests – in Feynman's words – has been the one for “wheels within wheels” – the task of natural philosophy being to discover the innermost wheels if any such exist. A second quest has concerned itself with the fundamental forces which make the wheels go around and enmesh with one another. The greatness of gauge ideas – of gauge field theories – is that they reduce these two quests to just one; elementary particles (described by relativistic quantum fields) are representations of certain charge operators, corresponding to gravitational mass, spin, flavor, color, electric charge, and the like, while the fundamental forces are the forces of attraction or repulsion between these same charges. A third quest seeks for a unification between the charges (and thus of the forces) by searching for a single entity, of which the various charges are components in the sense that they can be transformed one into the other.

But are all fundamental forces gauge forces? Can they be understood as such, in terms of charges – and their corresponding currents – only? And if they are, how many charges? What unified entity are the charges components of? What is the nature of the charge? Just as Einstein comprehended the nature of gravitational charge in terms of space-time curvature, can we comprehend the nature of the other charges – the nature of the entire unified set, as a set, in terms of something equally profound? This briefly is the dream, much reinforced by the verification of gauge theory predictions. But before I examine the new theoretical ideas for the future in this particular context, I would like your indulgence to range over a one-man, purely subjective, perspective in respect of the developments of the last twenty years themselves. The point I wish to emphasize during this part of my talk was well made by G.P. Thomson in his 1937 Nobel Lecture. G.P. said: “... The goddess of learning is fabled to have sprung full grown from the brain of Zeus, but it is seldom that a scientific conception is born in its final form, or owns a single parent. More often it is the product of a series of minds, each in turn modifying the ideas of those that came before, and providing material for those that come after.” [...] ²

² The complete text of the Nobel Lecture is beyond the scope of the present volume. It is easily available in a number of publications on Dr. Abdus Salam.

*Opening Address by Professor Sune Bergström,
President of the Nobel Foundation,
December 10, 1979*

Your Majesties, Your Royal Highnesses, Ladies and Gentlemen,

The Nobel Foundation takes special pleasure in welcoming you all, laureates of 1979. You have delivered excellent lectures, but the many scientific and personal contacts we have had with you have also been most stimulating and pleasant.

Alfred Nobel stipulates in his will that his Prize go to those who have conferred the greatest benefit on mankind.

The Nobel Prize in physics, chemistry, and medicine have often recognized pioneering research achievements at the frontiers of our knowledge: enterprises, therefore, that usually can only be understood and judged by a small group of specialists.

This is in keeping with Nobel's wish that principal encouragement go to basic and pioneering research, whose results can be expected to lead to practical, significant developments of "benefits" to mankind.

The concept of "benefit" just therefore generally be accorded a somewhat long-range view – even though discoveries already benefiting humanity are not infrequent recipients of the Prize.

Let us hear now what an older Swedish contemporary of Nobel's had to say about research and its applications. He was a man who doubtless had an influence – albeit an indirect one – on the young Nobel. "The importance of scientific applications has grown so great in recent years that, in several nations, it has become the principal focus of scientific enterprise. This need not be regretted, but if scientific activities cease to be pursued for their own sakes and are engaged in solely with regard to applications, then they will soon become static, and little or nothing new will be gained anymore ..."

What is interesting is that this declaration was made in 1822 by Berzelius, who was born two hundred years ago and died when Nobel was fifteen. He pioneered the Swedish chemical and medical sciences and brought them to positions of international stature – despite the fact that, in those days, by all our modern criteria, Sweden was indeed a "developing" country. As late as around the mid-1800s, half of all Swedish children were still dying before age five, and the country was ravaged by severe famines on numerous occasions. It took Sweden, as it took other now-industrial nations, about a century to reach what we now regard as a fairly decent standard of living.

But Swedish authorities, and authorities elsewhere in Europe, were already interested in higher education and in the research taking place at universities and academies. Even though the university-educated portion of the population was

extremely small, it played an important role in development through its knowledge, its power of initiative, and its international contacts.

Today, perhaps, half of mankind's four thousand million people are living under sanitary and economic conditions akin to those of western Europe's majority of one hundred and fifty years ago. But today, there is no century available for those people's development. Radical improvements must be carried out within one or two decades: anything else is humanly and politically unacceptable.

What role, then, does research play in this process?

In the 1950s and 1960s, it was a not-uncommon belief in many aid circles that the industrial countries possessed sufficient knowledge and technology to solve the problems of the developing countries. All that was needed was the expenditure of enough energy to ensure the distribution and utilization of that knowledge and technology.

By now, however, even though our present knowledge is by no means being fully utilized, probably everyone realizes that vigorous research-and-development efforts are needed in most fields to give progress the necessary speed and at the same time to ensure avoidance of the same errors that we have had to endure in this century.

It is thus only through the most advanced research and development work on the harnessing of solar energy that the tropical developing countries' energy requirements can be solved without disastrous environmental pollution under the increasing pressures of growing populations in the next half century.

The most advanced biomedical and chemical research efforts are needed to quickly produce better preventive and curative methods of controlling the serious tropical diseases that are now the scourges of hundreds of millions of people.

Large portions of this and other necessary research and development can doubtless be carried out best and most rapidly in the industrial nations. But it is of central importance that the developing countries' own scientific and technological competence be built up at the same time so as to ensure continued and constant local development.

It is a tragic fact in many developing countries that the most sophisticated technology is represented by imported military equipment. If, at the same time, the civilian sector works with the simplest technology conceivable, then an intellectual imbalance ensues that is inimical to educational recruitment, among other things.

An expansion of entities of higher learning and research must proceed in parallel with increased efforts in other urgent fields, such as elementary education, health services, water supplies, and the economic development that this year's Economics Prize has highlighted.

The responsible politicians in the developing countries must thus support the long-range build-up of higher education and research.

This demands only relatively modest financial investments – but then all that much greater personal commitment and increased collaboration between the scientists and researchers of the developing countries and the industrial countries. As Odysseus Elytis put it in one of his prose works, freely translated as follows: “When people are united in collaboration, such potent and unexpected forces can arise that what had been regarded as immutable can, in fact, be changed or melted down. The force of scientific development is so great that one must optimistically believe that the forces of good, too, must triumph in our problem-filled world.”

The Peace Prize being presented today in Oslo exemplifies to us as well how the forces of good can be harnessed in realistic, humanitarian work and how deep religious faith, devoted to the service of humanity, does not hinder collaboration between peoples of different creeds.

This year's laureates fulfill all of Alfred Nobel's hopes and intentions. Our delight at their contributions is no small element of this day's festivities.

*The Nobel Prize for Physics Speech
by Professor Bengt Nagel of the
The Royal Academy of Sciences*

Your Majesties, Your Royal Highnesses, Ladies and Gentlemen,³

This year's Nobel Prize in Physics is shared equally between Sheldon Glashow, Abdus Salam and Steven Weinberg “for their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including inter alia the prediction of the weak neutral current”.

Important advances in physics often consist in relating apparently unconnected phenomena to a common cause. A classical example is Newton's introduction of the gravitational force to explain the fall of the apple and the motion of the moon around the earth. In the 19th century it was found that electricity and magnetism are really two aspects of one and the same force, the electromagnetic interaction between charges. Electromagnetism, with the electron playing the leading part and the photon – the electromagnetic quantum of light – as the swift messenger, dominates technology and our everyday life: not only electrotechnics and electronics, but also atomic and molecular physics and hence chemical and biological processes are governed by this force.

When one began to study the atomic nucleus in the first decades of our century, two new forces were discovered: the strong and the weak nuclear forces. Unlike gravitation and electromagnetism these forces act only over distances of the order of nuclear diameters or less. The strong force keeps the nucleus together, whereas the weak force is responsible for the so-called beta decays of the nucleus. Most radioactive substances used in medicine and technology are

³ Translation from the Swedish text.

beta radioactive. The electron also participates in the weak interaction, but the principal part is played by the neutrino, a particle, which is described as follows in a poem by the American writer John Updike:

COSMIC GALL

Neutrinos, they are very small.
They have no charge and have no mass
And do not interact at all.
The earth is just a silly ball
To them, through which they simply pass,
Like dustmaids down a drafty hall
Or photons through a sheet of glass. ...
At night, they enter at Nepal
And pierce the lover and his lass
From underneath the bed – you call
It's wonderful; I call it crass.

The description is accurate, apart from the statement “they do not interact at all”; they do interact through the weak force. The neutrinos of the poem, entering the earth at night at Nepal and exiting in the United States in a sort of reversed China syndrome, come to us from the center of the sun. Solar energy, necessary for life on earth, is created when hydrogen is burnt to helium in the interior of the sun in a chain of nuclear reactions – even the advocates of “Solsverige” must ultimately rely on nuclear energy although it must be said that the fusion reactor Sun is well encapsuled and sufficiently relocated away from population areas. The first igniting and moderating link in this chain, burning hydrogen to deuterium, is based on the weak force, which could then be called the Sunignator and Suntamer.

The theory which is awarded this year's prize, and which was developed in separate works by the prizewinners in the 60s, has extended and deepened our understanding of the weak force by displaying a close relationship to the electromagnetic force: these two forces emerge as different aspects of a unified electroweak interaction. This means, for example that the electron and the neutrino belong to the same family of particles; the neutrino is the electron's little brother. Another consequence of the unified theory is that there should exist a new kind of weak interaction. It was formerly assumed that weak processes could occur only in connection with a change of identity of the electron to neutrino (or vice versa); such a process is said to proceed by a charged current, since the particle changes its charge. The theory implies that there should also be processes connected with a neutral current in which the neutrino – or else the electron – acts without changing identity. Experiments in the 70s have fully confirmed these predictions of the theory.

The importance of the new theory is first of all intrascientific. The theory has set a pattern for the description also of the strong nuclear force and for efforts to integrate further the interactions between elementary particles.

Let me end by giving an example of the intricate links which exist between different branches of natural science.

Our body is to a large part constructed from "stardust": the elements besides hydrogen which build our cells have been formed in the interior of stars in nuclear reactions, which form a continuation of the processes taking place in our sun. According to the astrophysicists, certain heavy elements appearing in life – important enzymes and hormones – iodine and selenium are examples of such elements – can probably only be created in connection with violent explosions of giant stars, so-called supernova explosions, which occur in our Galaxy once every one or two hundred years. It is likely that neutrinos interacting via the neutral current play an important role in these explosions, in which a large part of the matter of the star is thrown out into space. Thus, for our functioning as biological beings we rely on elements formed milliars of years ago in supernova explosions, with the new kind of weak force predicted by the theory contributing in an important way; really a fascinating connection between biology, astrophysics and elementary particle physics.

Professors Sheldon Glashow, Abdus Salam, and Steven Weinberg,

In my talk I have tried to give a background to your great discoveries in the borderland between a strange but known country and the probably large unknown territory of the innermost structure of matter.

Our way of looking at this structure has changed radically in the last decade. The theory of electroweak interaction has been one of the most important forces to bring about this change of outlook.

It is a privilege and a pleasure for me to convey to you the warmest felicitations of the Royal Swedish Academy of Sciences and to invite you to receive your prizes from the hands of his Majesty the King.

Remarks at the Nobel Banquet by Dr. Abdus Salam

Your Majesties, Excellencies, Ladies and Gentlemen,

On behalf of my colleagues, Professors Glashow and Weinberg, I thank the Nobel Foundation and the Royal Academy of Sciences for the great honor and the courtesies extended to us, including the courtesy to me of being addressed in my language Urdu. Pakistan is deeply indebted to you for this.

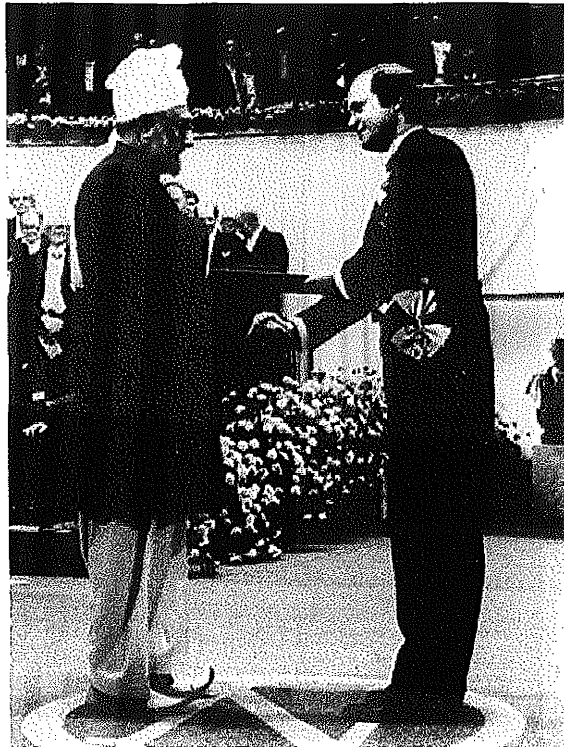
The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says: "Thou seest not, in the creation of the All-Merciful, any imperfection.

Return thy gaze, seest thou any fissure. Then return thy gaze, again and again. Thy gaze comes back to thee dazzled, and made dim." (*Al-Qur'an*, 67: 3-4)

This in effect is the faith of all physicists; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze.

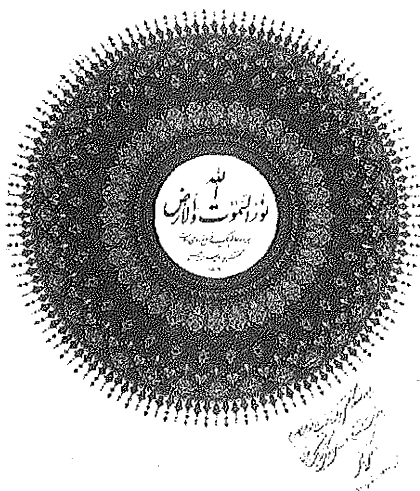
I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resource.

Alfred Nobel stipulated that no distinction of race or color will determine who receives of his generosity. On this occasion, let me say this to those whom God has given His Bounty. Let us strive to provide equal opportunities to all so that they can engage in the creation of physics and science for the benefit of all mankind. This would exactly be in the spirit of Alfred Nobel and the ideas which permeated his life. Bless you ■

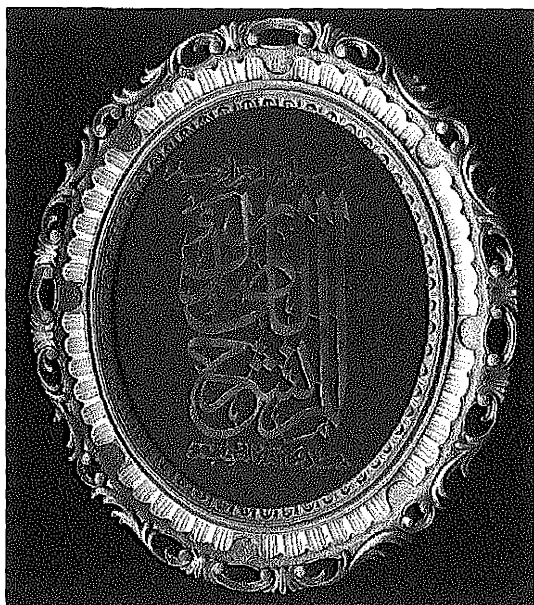


37. Receiving the Nobel Prize for Physics from the King of Sweden, 1979

Islamic Calligraphs in the Abdus Salam Room, ICTP



38. "God is the Light of the Heavens and the Earth" (Al-Qur'an)



39. "Have We not opened up your mind [and lifted the burden...]?"
(Al-Qur'an)

20

Islamabad Lecture

Mr. President, Excellencies, Ladies and Gentlemen,

I wish to start with grateful thanks to Allah for the very great honor the nation and you have done to me by the conferment of this Degree, by the holding of this celebration and by inviting with personal solicitude, my family, and most importantly, my teachers to it. I have been overwhelmed by the affection of the nation, and from all over the world of Islam and I find no words to render adequately my praise and thanks: "That is the grace of Allah which He bestows on whom He pleases. And Allah is the owner of infinite bounty." (*Al-Qur'an*, 57:21)

The theory for which I have been honored concerns the fundamental forces of Nature. Until two decades ago, physicists believed that there are four fundamental forces of Nature; the gravitational, the electromagnetic and the two nuclear forces, the weak and the strong. Two decades ago, my colleagues and I suggested that there were indications that the weak nuclear force was not really different from the electromagnetic and that the two could interconvert, one into the other. We were searching for a unity, in the tradition of Newton, Maxwell and Einstein, and the unified theory was formulated in its final form in 1967, at Imperial College, London, and the International Centre for Theoretical Physics at Trieste with which I have the privilege of being associated, and also independently at Harvard.

The first indication of the theory's correctness came in 1973, when the great European Nuclear Research Laboratory at Geneva (CERN) found experimental evidence of neutral currents, which are an essential part of the predictions of the theory. The clinching evidence was provided last year by the Stanford Linear Accelerator in the United States, which, in an epic experiment, confirmed its second aspect – its heart as it were – of the unification of the electromagnetic force with the weak nuclear to one part in four thousand as predicted. An experiment at Novosibirsk by a group led by Professor Barkov further confirmed this. To these and to other great laboratories situated in Europe, the United States and the USSR, I wish to express my appreciation for the remarkable series of

Address on the occasion of the award of the D.Sc. degree by the University of Islamabad, December 18, 1979.

experiments which have now confirmed that the weak nuclear force is indeed basically the same as the electromagnetic.

The next task is to test if the third force (the strong nuclear) is also part of this unity. Together with some colleagues, we have formulated this and suggested experiments to test the idea. If the results are positive, in about five years, with Allah's grace, we shall have reduced the four forces to just two.

Then will remain the final goal of uniting gravity with this electronuclear force. It is our faith that this must also be true, but a precise formulation and its confirmation may take fifty years to achieve. Let me hope and pray that this final challenging problem is resolved by a young future Prize-winner from Pakistan.

Mr. President, the fact that we were seeking a unity among the seemingly disparate forces of nature is part of our faith as physicists and of mine as a Muslim. Just eight days back, I was asked to reply on behalf of the physics Prize winners to the Banquet address of His Majesty the King of Sweden in the great and glittering Banquet Hall of Stockholm. With your indulgence, I shall read out part of what I said, for it bears on this faith in the ultimate unity and symmetry of Nature.

The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says: "Thou seest not, in the creation of the All-Merciful any imperfection. Return thy gaze, seest thou any flaw? Then return they gaze, again and again. Thy gaze comes back to thee dazzled and made dim." (*Al-Qur'an*, 67:3-4)

This, in effect, is the faith of all physicists; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze.

I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge, for lack of opportunity and resource.

To emphasize that science is the shared heritage of mankind and that the history of science, like the history of all civilization, has gone through cycles, I recalled in my Nobel lecture an historical episode. Some seven hundred and sixty years ago, a young Scotsman left his native glens to travel south to Toledo in Spain. His name was Michael, his goal to live and work at the Arab universities of Toledo and Cordoba. [...]

George Sarton, in his monumental five-volume History of Science, chose to divide his story of achievements in sciences into ages, each age lasting half a century. With each half century he associated one central figure. Thus, from 450 to 400 BC, Sarton calls the Age of Plato; this is followed by half centuries of Aristotle, of Euclid, of Archimedes and so on. From 600 AD to 700 AD is the Chinese century of Hsüan-tsang and I Ching and then from 750 AD to 1100 AD – three hundred and fifty years continuously – it is an unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Avicenna, Ibn al

Haitham and Omar Khayam – Arabs, Turks, Afghans and Persians – men belonging to the culture of Islam. After 1100 AD, the first Western names appeared: Gerard of Cremona, Roger Bacon – but the honors are still shared with the names of Ibn-Rushd, Musa ibn Maimun [Maimonides], Tusi and Ibn-Nafis – the man who anticipated Harvey's theory of circulation of blood.

After 1350 AD, however, the developing world loses out except for the occasional flash of scientific work, like that at the court of Ulugh Beg, the grandson of Timurlane, in Samarqand in 1437 AD; or of Maharaja Jai Singh of Jaipur in 1720, who at the court of Muhammad Shah in Delhi corrected the serious errors of the Western tables of eclipses of the sun and the moon by as much as six minutes of arc and published *Zijj Muhammad Shahi*. This brings us to this century when the cycle begun by Michael the Scot turns full circle and it is we in the developing world who turn Westwards for science, with C.V. Raman, the first towering figure from the developing world, in 1930. As Al-Kindi wrote 1100 years ago: "It is fitting then for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us. For him who scales the truth, there is nothing of higher value than truth itself, it never cheapens nor abases him who seeks."

But why did we lose out? No one knows for certain. For the lands of Islam, there were external causes, like the invasion of Mongols but there was, in my view, something deeply internal also. To illustrate the apathy that came over us, I shall quote from Ibn-Khaldun, one of the greatest historians of all times, who wrote two hundred years after the journeys of Michael the Scot and Hendrik the Dane were undertaken to acquire knowledge from the World of Islam. Ibn-Khaldun writes, "We have heard of late that in the land of the Franks, and on the northern shores of the Mediterranean, there is a great cultivation of philosophical sciences. They are said to be studied there again and to be taught in numerous classes. Existing systematic expositions of them are said to be comprehensive, the people who know them numerous and the students of them very many. Allah knows better what exists there, but it is clear that the problems of physics are of no importance for us in our religious affairs. Therefore, we must leave them alone."

Ibn-Khaldun displays no curiosity, no wistfulness, just apathy, bordering on hostility. Mr. President, I would like here to pause and reflect with you. We are convinced today of the need for acquiring science and technology and for recovering our lost heritage. But before this happens, we must arouse the spiritual energies, particularly of the younger generation, for science and technology. Permit me, therefore, to say a few words on this subject with reference to Islam.

The reason why the Muslims searched for and developed sciences in their Golden Age, in the eighth, ninth, tenth and eleventh centuries is not hard to seek. The Muslims were following the repeated injunctions of the Holy Book and the Holy Prophet. According to Dr. Mohammad Aijazul Khatib of Damascus University, nothing can emphasize the importance of science more than the remark that "in contrast to 250 verses which are legislative, some 750 verses of

the Holy Qur'an – almost one eighth of it – exhort the believers to study Nature, to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the Community's life."

I do not have to remind this audience of the proud title of the "Inheritors of the Prophets" which the Holy Prophet accorded to the 'ulema, the men of knowledge: "The scholars are the inheritors of Prophets."

The Holy Qur'an emphasizes the superiority of the 'alim, the man with knowledge: "Can those who know not, ever equal those who know?" And again: "Only those of his servants who possess knowledge fear Allah."

I have translated in these verses, the word '*ilm*' as "knowledge". The point I wish to make is that just a few months ago, Dr. Al-Muntassar, Rector of the Al-Fatah University in Tripoli, emphasized to me that in Arabic there is no word other than '*ilm*' for science. I would humbly like to suggest that in order to underline this emphasis on science, all religious seminaries must include studies of sciences – and not just the sciences as at the time of Avicenna – in their curricula just as the studies of religion are, and must be, part of the curricula of all schools and colleges in Pakistan.

But what about technology – of science in application? Again, if I may humbly suggest, the Holy Book emphasizes for the Community the acquiring of technology by holding forth the examples of David and Solomon, with their mastery of the technologies of their day. "And we made iron soft for him. ... We subjected the winds for him", in my interpretation through sail-power, and "under his command he had jinns", that is, again in my humble interpretation, controlled powers of the heavy machinery of the day, which fashioned building blocks, palaces, dams and reservoirs. And then we are reminded of Dhul-Qarnain, building defences with blocks of iron and molten copper. Thus are the technologies of metallurgy, heavy construction, wind-power and communications emphasized. As every Muslim knows, the Holy Book does not relate, except as an exhortation for the future and as an example to be followed by the Community. "Such are the parables which We put before mankind so they may reflect." (*Al-Qur'an*, 59:21)

But how are we to acquire this desired mastery of science and technology today? Again, I would like to submit, in keeping with our own experience of earlier centuries and the experience of others, that there are no short cuts. A nation has to commit itself with a passionate commitment; it must impart hard scientific and technological training to more than half of its manpower; it must pursue basic sciences as well as applied technology with some 1-2% of its GNP spent on research and development alone. This was done by Japan, starting with the Meiji revolution towards the end of the last century, when the Emperor took an oath that knowledge will be acquired from wherever it could be found from the far corners of the earth. This was done recently by Korea with its Five Year Plan for Science; this is being done in a planned manner today at a frantic speed by our great and friendly neighbor, the People's Republic of China, with a pledge

to catch up with the West in genetic engineering, in biology, in high energy physics, in space technology, in electronics, and in fusion physics, by the year 2000, irrespective of cost in sacrifices to the society. We too shall have to follow these norms, if we wish to succeed. But we must not pitch our ambitions too low, for there is no reason that they cannot be realized.

Mr. President, there is nothing worse in this respect than a sub-critical scientific technological community, starved of younger manpower which alone can rejuvenate it, starved of scientific literature and tools, and worst of all, starved of frequent international contacts with their peers elsewhere.

In this respect, one must state categorically that science is not cheap. Investment in it needs sacrifices on the part of the nation as a whole and not just the Government. As I said before, international norms of spending on scientific and industrial research by a community must be around 1-2% of the gross national product. Pakistan has a GNP of the order of \$10 billion. It should be spending some \$100 million a year on scientific and technological research alone. Mr. President, I do not know the figures for today, but when I was concerned with science in Pakistan some ten years ago, these figures did not exceed \$8 million and this included the then East Pakistan. We were a factor of ten short in comparison with what we should have been doing in research and development, with the same shortfall in percentages holding for the numbers of scientists and technologists we have and were training, at all levels.

But it is not just the expenditures, which are inadequate. Even more important than this is the will to utilize science and the scientists in every sphere of national development. As I said before, it is an amazing fact that the Koreans have increased their GNP by a factor of ten in ten years – from \$100 per capita to \$1000 per capita between 1970 and 1979. This, I was told by Cabinet Ministers down to Physics Professors in Seoul, was achieved by their five-year plan of science and technology, fully integrated into the investment plan of the nation as a whole. The corresponding situation in Pakistan is that the Planning Commission even today does not boast of a science and technology cell. In order that science and technology can make an impact, it is imperative that the scientists and technologists must be given the ultimate responsibility for the application of advances in knowledge. No administrator can do or should attempt to do this for them. Rather, there should be, like in Japan, like in China, like in Korea, like in Sweden, like in France, in my personal experiences, the most complete accord between the scientist, the technologist and those who run the development machinery of the state and the industry, with full trust in their respective spheres on all sides.

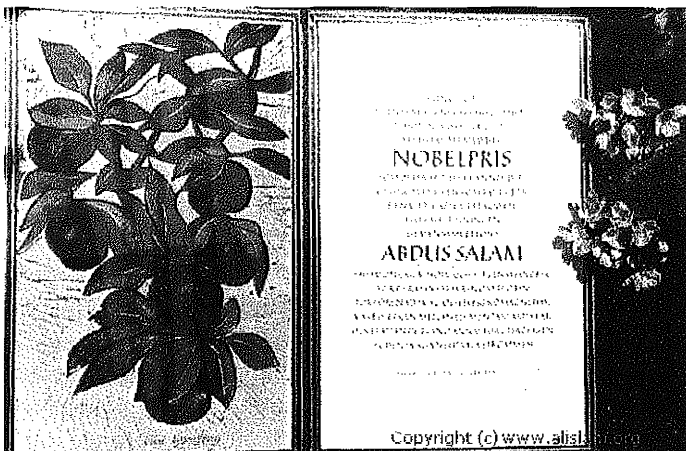
I remember hearing the late Lord Mountbatten once give a lecture at the Royal Society. He was narrating his experience during the war in working with scientists like Sir Solly Zuckerman, A.V. Hill and the future Nobel Laureate, P.M.S. Blackett. Lord Mountbatten recalled that at the first meeting with the scientists in 1939, he presented them with a list of war problems, which the

services had specified for the scientists to solve. Mountbatten remembered that Zuckerman simply laughed at the presentation of the list saying, "Please do not specify what you think are the problems. Take us into your confidence; tell us your objectives and let us define in our own manner the obstacles and problems. We shall then jointly endeavor to find solutions to meet the precise objectives you have set us."

Mr. President, the celebrations of today could represent a landmark for science and technology if they succeed in removing from the youth of our nation any feeling of inadequacy when faced with modern science and technology. The celebrations will have served a purpose if the nation feels spiritually united and if the conflict between religion and science the younger generation feels is felt no longer, for there indeed is no conflict in Islam. These celebrations will have served a purpose if Pakistan lays the foundations for a five-year plan for science and technology and its application to development with the scientist and the administrator, respecting, trusting and fully collaborating with each other.

Mr. President, my own remaining as a physicist was due to a series of fortunate accidents, economic and otherwise. I shall not elaborate on them here, but you, personally, having suffered from some of the same disabilities, will understand. There is need for those whom Allah has given of His bounty, to give of it to the nation's young, to support science and scientists, so that no talent is wasted. No Government alone can do this; my appeal is to the nation as a whole, which must respond generously with the setting up of funds for talent everywhere.

The recognition you have celebrated today has come in the last year of the 14th century of Hijra. Let me end with the prayer that the new century of Hijra dawns with similar recognitions for this nation and for the World of Islam with great frequency every year. Amen. ■



41. Plaque of the 1979 Nobel Prize for Physics

21

Einstein's Last Dream: The Space-Time
Unification of Fundamental Forces

From the earliest times, man's dream has been to comprehend the complexity of Nature in terms of as few unifying concepts as possible. In this context, in the history of physics, three names stand together; those of Newton, Maxwell and Einstein, as among the greatest synthesizers and unifiers of all times. Newton, some three hundred years ago, identified and unified terrestrial gravity (the force which makes apples fall) with celestial gravity (the force which keeps planets in orbit around the sun). Maxwell, two hundred years later, unified the forces of electricity and magnetism. He further showed that light was one manifestation of this unification. Einstein, in 1905, unified the concepts of space and time. Eleven years later, he could show that Newton's gravity was a manifestation of this audacious unification in the sense that Newtonian gravity signified a curvature of the united space-time manifold. The question, which Einstein then asked was this: Could Maxwell's electromagnetism be united with Newtonian gravity in the same way that Maxwell had united electricity and magnetism? If so; was Maxwell's electromagnetism also a manifestation of some other geometrical property of the space-time manifold; just as Newtonian gravity was a manifestation of its curvature. This was Einstein's last dream, about which I have been asked to speak today. In 1979, it appears that Einstein's was a very valid dream and there is progress towards its realization, which I am sure he would have rejoiced to see.

To set the scene, let us summarize what we have known since around 1935, regarding the ultimate building blocks of which all matter in the Universe is made and the forces, which govern the behavior of matter. I shall forego introducing some concepts, which are irrelevant to my theme today: stated in its simplest form, essentially all matter we see around us is made up of four building blocks, four basic particles. These are the two nuclear particles, the proton (P) and the neutron (N) and the two so-called light particles, the electron (e) and the

Address at the UNESCO Celebration of the Centenary of Albert Einstein's Birth, May 7, 1979, Paris. This version was the first R.D. Birla Memorial Lecture delivered under the auspices of the Indian Physics Association at Bombay on January 9, 1981. First published in *Physics News*, Vol. 12, No. 2 (June 1981).

neutrino (ν). There are four basic forces, which govern the behavior of these particles, when they come close to each other. These four forces are the following:

1) *The Gravitational Force.* All four particles (P, N, e, ν) attract each other with a force, which is proportional to their mass. This is the force which controls the behavior of planets, stars, galaxies and which determines the overall features of the Universe we live in.

2) *The Electromagnetic Force.* Of the four particles, two, the proton and the electron are electrically charged. The other two are electrically neutral. Protons attract electrons, the strength of the electromagnetic force between them being proportional to their electric charges. The proton-electron force is responsible for holding atoms together. It is this force, which chiefly governs all known phenomena of life on earth.

3) *Weak Nuclear Force.* All particles P, N, e, ν also interact with each other through a weak nuclear force provided they are close to each other than 10^{-16} cm, and are in a state of left polarization. This force was discovered in the early part of this century; it gives rise to the phenomenon known as β -radioactivity and is principally responsible for the existence of heavy elements on earth and other parts of the Universe.

4) *Strong Nuclear Force.* Protons and neutrons carry a strong nuclear charge (in addition to the weak nuclear charge). These particles attract each other strongly when closer than 10^{-13} cm. The strong nuclear force is responsible for holding the nuclei of He, Li, Be, C, U, etc., together. The phenomena of fusion, responsible for making the sun shine, and fission which powers present generation of nuclear reactors are aspects of this force.

The picture presented above of four basic entities and four basic forces between them represents a remarkable economy in concepts. But even this remarkable economy is not enough for the physicist. Just as Maxwell and Faraday had shown that the seeming distinction between electricity and magnetism depended on whether electric charges producing these forces were stationary or in motion, in a like manner the physicist has hoped that he could unify the four seemingly distinct forces into one single basic force of which the four known ones are different facets. Einstein went further; he wished to comprehend this single unified force – assuming that it existed – as a geometrical property of the space-time manifold we live in. If this dream of unification is true, there would, of course, be measurable consequences, which would follow from the unification of forces and their enshrinement within space-time structure.

What exactly does the unification of forces mean, can be illustrated by a historical survey of the unification ideas.

History of Unification Ideas in Physics

1) We start with the Islamic physicist Al-Biruni (working in the 11th century) and Galileo: they declared that laws of physics, discovered here on

earth, apply equally to phenomena occurring elsewhere in the Universe. Galileo in particular made the concept more precise, by his observations regarding the mountains on the moon. This faith in the unity of nature now underlies the whole science.

2) Newton (born the year of Galileo's death) quantitatively realized some three hundred years ago, Galileo's ideas, by recognizing and postulating the law of universal gravity; in particular by showing quantitatively that the terrestrial force which governs falling bodies on earth is identical with celestial gravity – the force which keeps planets in orbits around the sun.

3) One hundred and fifty years after Newton, Faraday and Ampere showed that magnetic forces are produced by electric charges in motion. This was the beginning of the unification of till-then the two disparate forces of nature – electricity and magnetism.

4) The work of Faraday culminated with Maxwell, the centenary of whose death will fall this year in November. Maxwell showed that a manifestation of the unification of electricity and magnetism must mean the production by accelerating electric charges of electromagnetic radiation – in the form of radiant heat, light, radio and X-rays. These radiations are nothing but aspects of the electromagnetic force.

5) Fifty years later, the work of Heisenberg, Schrodinger and Dirac showed that chemical forces – among which are included all forces which govern life and neurological functions – are yet another manifestation of electromagnetism plus quantum theory.

6) In 1905, Einstein unified the concepts of space and time. In 1906, building on this, and generalizing the unification concepts still further, he showed that Newtonian gravity was a manifestation of the curvature of the space-time manifold. This audacious concept of a dynamic space-time led to spectacular advances in cosmology; predicting on the one hand an expansion of the universe (substantiated by the observed red shift of distant galaxies) and on the other hand predicting the 3°K remnant of a big bang which signaled the “birth” of the Universe some 10^{10} years ago.

7) Finally, as the culmination of his life work, Einstein wished to see a unification of gravity and electromagnetism as aspects of one single force. In modern language he wished to unite electric charge with the gravitational charge (mass) into one single entity. Further, having shown that mass – the gravitational charge – was connected with space-time curvature, he hoped that the electric charge would likewise be so connected with some other geometrical property of space-time structure.

8) But where did the weak and the strong nuclear forces – and the weak and strong nuclear charges – come into this? Gravity and electromagnetism are but two out of the four basic forces. It is here that the recent post-Einsteinian developments I wish to describe are relevant.

We believe that the electromagnetic charge and the weak and the strong nuclear charges are so akin to each other – in the fact recently shown that all these charges can only exist in discrete units – that the first stage of unification would bring electromagnetism and the nuclear forces together. Once this is accomplished a second stage of unification would unify this combined force with gravity and possibly also realize Einstein's dream of comprehending the final unified force within the geometry of space-time.

It is difficult to describe the theoretical arguments, which have led us to this conclusion. But there are experimental consequences, which follow from the suggestion of the unification of the electromagnetic with the weak nuclear force.

The most spectacular predication, verified last year at the Stanford Linear Accelerator Center was the following. If indeed the weak nuclear force is nothing but a different facet of a basic force whose other facet is electromagnetism, electromagnetism – the force between electrons and protons – when carefully examined should show some characteristics which one had in the past associated with the weak nuclear force only. One such characteristic is the distinction of force experienced by left-spinning versus right-spinning electrons. The SLAC experiment, measuring this deflection with an accuracy never before attempted, demonstrated that left-spinning electrons indeed are deflected one part in ten thousand times more than right-spinning electrons when scattered off heavy water. To one part in ten thousand – just as the theory predicted – what was previously thought of as the distinct weak nuclear force intrudes into the hitherto separate domain of electromagnetism, clinching the hypothesis that the two forces are indeed facets of one basic fundamental force and are intertwined one with the other.

There is a second prediction, even more spectacular. It states that the apparent differences – short-range character of the weak nuclear versus long-range character exhibited by the electromagnetic force – are simply a consequence of the circumstance that we happen to live in an epoch some 10^{10} years after the big bang, when the Universe has cooled to a temperature of 3°K . If we had been privileged to live and experiment one-tenth of a second after the birth of the Universe, both forces, the weak-nuclear and the electromagnetic would have been long range. Of course we cannot travel backwards in time; but we can quantitatively predict the precise difference in range of the weak nuclear force versus the electromagnetic. The precise prediction is that if these two forces are truly facets of a basic "electroweak" force, then there must exist two new heavy elementary particles with masses ~ 80 and 90 times proton mass, the first charged, the second electrically neutral. The particles are predicted to be the mediators of the weak nuclear force just as the photon is the mediator of the electrical force. The European Nuclear Research Laboratory (CERN) which UNESCO helped to found in 1954, is tooling itself just now to produce the

requisite energetic beams of protons and anti-protons with its new accelerator, commissioned five years ago. If suitably energetic beams can be produced, one may expect that during 1982, experiments to check if the predicted particles exist will be carried out. If such energetic beams are impossible to produce – and there are formidable difficulties in attaining the requisite intensity – one shall need a new particle accelerator with verifying energies and intensities still higher to clinch the matter. This experiment – the existence of the electroweak particles and in particular the heavy photon – is in some ways on par with the 1919 eclipse measurement of deflection of light which established Einstein's theory of gravity. This time it is the unification of the weak nuclear force with the electromagnetic which is at stake. At present all indirect experimental evidence already points in the direction that the electroweak unification hypothesis is correct, that the predicted particles do indeed exist. There are not four, but three basic forces of nature.

After this experiment is done, or perhaps simultaneously with it, there will be a test of the possible unification of the strong nuclear force with the electroweak force – reducing the four basic forces to just two. This test consists of storing 10,000 tons of water in a mine one mile deep, shielding the water from all external sources of radiation. This mass of water will be surrounded by light-detecting devices. One proton out of the 10^{33} protons which make up this mass of water will turn (in the span of a year) into a positron, emitting light of a characteristic wavelength. This will be the signal of the grand unification into one force of three of the four forces – electromagnetic, weak-nuclear and the strong-nuclear.

But what of Einstein's first dream of finally unifying this electro-nuclear force with gravity – and then the second dream of this new unified force being a manifestation of the structure of space-time? Amazingly, in the optimistic climate of physics today, these dreams also seem near to realization. It could be that space-time has extra dimensions besides the four that we are conscious of – it would be that the extra dimensions are associated with the electric and the nuclear charges just as the gravitational charge is associated with the curvature of the four space-time dimensions we are familiar with. It could be that, as suggested by Wheeler, the electric and nuclear charges are telling us about the small scale structure of space-time, of foam-like granularities, which are smoothed out when one observes coarsely. Space-time may be like some varieties of cheese with holes at places where charges are located. Some of these ideas were already formulated when Einstein lived. On some of these he worked himself. Somehow, today with the electroweak unification already in the offing, they appear near to be realized.

I was amused to read the Science and Technology section of the prestigious British Journal, *The Economist*, issue of March 10, 1979, commemorating

Einstein's birthday. *The Economist* discusses the unification of forces I have described above and then goes on to say: "If nature is really that simple, and there is only one fundamental force, then industry should be thinking about its long-term research programs. It may eventually prove sensible to harness the other forces to new technologies, by manipulating them with electromagnetism. Nobody can predict just what the applications might be. But then, when Maxwell realized over a hundred years ago, that electricity and magnetism were just different aspects of the same electromagnetic force, nobody foresaw that this would help lead to radios, telephones, televisions and the whole of electronics." Surely, Einstein never bargained for this when he dreamt about uniting Maxwell's theory with Newton's through the crucible of a dynamic space-time.

I wish to conclude with one thought, which I would like to share with you.

There has been no one like Einstein in this century; perhaps never in the whole history of human thought, so far as physical sciences are concerned. Certainly there never has been anyone so singly responsible for so much revolutionary thinking in physics.

But how easily may Einstein have been lost, particularly if he had been born in a developing country. At the age of fifteen he was summoned by one of his teachers at the Luitpold Gymnasium in Munich; the teacher expressed the wish that Einstein leave the School. In Einstein's words, "To my remark that I had done nothing amiss, he replied only, "Your mere presence spoils the respect of the class for me." This was a reference to Einstein's independence.

At the age of sixteen and a half, Einstein wished to enter the Zurich Polytechnic. He took the Entrance Examination for Engineering and, fortunately for physics, he failed. A year later, he succeeded, but by now he had given up all thought of becoming an engineer. Einstein graduated from the Zurich Polytechnic in the year 1900; he sought university positions, but failed "for I was not in the good graces of my former teachers." Einstein maintained himself by finding temporary jobs, performing calculations, private tutoring at three francs an hour, school-teaching. In November 1901, he submitted a research paper as a thesis for a doctorate's degree – a necessary passport for university teaching. Although this paper – his second – was accepted by the prestigious journal *Annalen der Physik*, the University of Zurich rejected it as inadequate for a Ph.D.

According to Banesh Hoffmann, Einstein felt himself sinking hopelessly in the quagmire of a world that had no place for him. A poignant episode during 1901 will illustrate what I mean. In 1901, Einstein's first research paper had been published in *Annalen der Physik*. Einstein sent a copy of this to Professor Wilhelm Ostwald – later a Nobel Laureate – with the letter: "Since I was inspired by your book on general chemistry ... I am taking the liberty of sending you a copy of my paper. I venture also to ask you whether perhaps you might have use for a mathematical physicist ... I am taking the liberty of making such a request only because I am without means. ..."

In spite of a second reminder there was no response from Ostwald, or from Professor Kamerlingh-Onnes in Leiden to whom Einstein sent a similar request.

At this stage, in Banesh Hoffmann's words, a beautiful event occurred in Einstein's life of which he knew nothing. Einstein's father, an unsuccessful merchant, in ill health, and a stranger to the academic community, took it upon himself to write to Professor Ostwald. Here is his letter: "I beg you to excuse a father who dares to approach you, dear Professor, in the interest of his son ... My son Albert Einstein is twenty-two years old ... Everybody who is able to judge praises his talent ... My son is profoundly unhappy about his present joblessness, and every day the idea becomes more firmly implanted in him that he is a failure in his career and will not be able to find the way back again ... Because, dear Professor, my son honors and reveres you ... I permit myself to apply to you with the plea that you read his article ... and hopefully that you will write him a few lines of encouragement so that he may regain his joy in life and his work ... My son has no idea of this extraordinary step of mine."

There was still no reply. Eventually as is well known, in 1902 Einstein did find a job at the Swiss Patent Office – first as Probationary Technical Expert, Third Class, and then with a promotion to Engineer, Second Class. It was here – far from adequate scientific libraries, far from the stimulating research atmosphere of a conventional university physics department, snatching precious morsels of time for his own surreptitious calculations, which he guiltily hid in a drawer when footsteps approached, Einstein produced his revolutionary papers on quantum theory of light and the unification of space and time, during 1905. And during all this time, he was without the precious Ph.D. "I shall not become a Ph.D. ... the whole comedy had become a bore to me." Thus wrote Einstein, for a second attempt at this degree made in 1905 had also failed. A third attempt did eventually succeed, but by then he did not need the Ph.D. any more for he had already become famous.

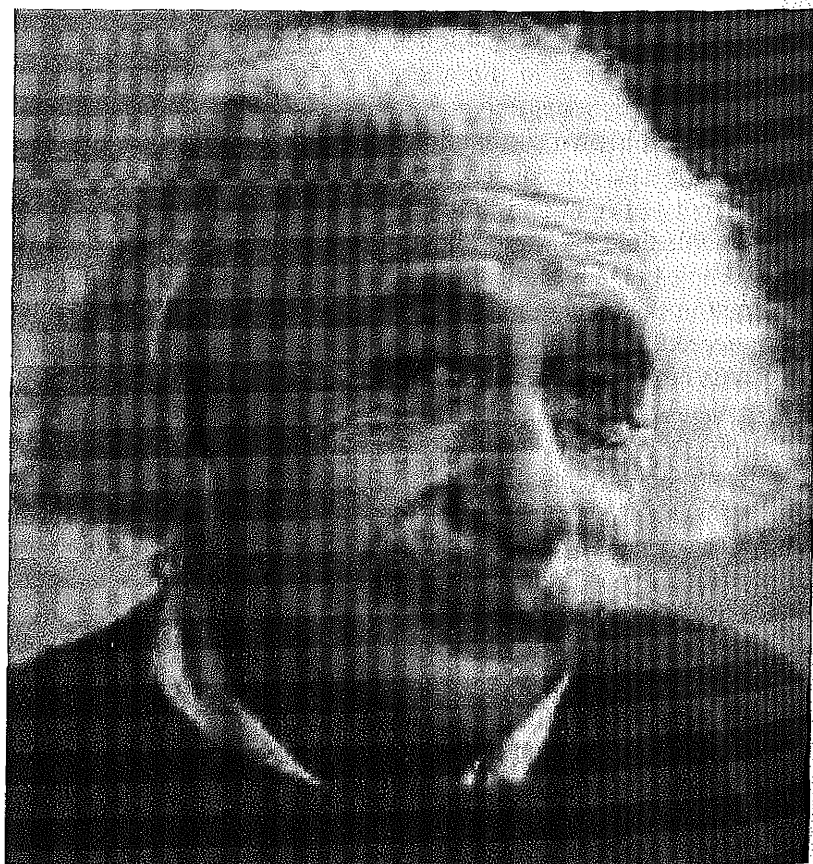
I have told this story in detail; for the simple reason that every one of the discouragements he suffered from was a norm for a scientist in a developing country. And even in a developed country today, would an Einstein, with his commitment to science for its own sake, fare any better? I shall quote first from Einstein and then quote a comment from Professor Reimar Lüst, President of Max-Planck Society.

"My scientific work is motivated by an irresistible longing to understand the secrets of nature and by no other feeling. My love for justice and striving to contribute towards the improvement of human conditions are quite independent from my scientific interests."

Professor Lüst's comment made during the Einstein celebrations at Bern was: "These words may sound strange to the ears of those who are responsible for science policy all over the world today, looking for social relevance,

immediate applicability and cost-benefit-analysis in supporting scientific research.”

I rejoice that UNESCO, representing the world community of culture and scholarship is commemorating in a befitting manner the centenary of Einstein – the greatest figure in the scientific culture of our times – perhaps all times. I am confident UNESCO will not forget Einstein’s ideal regarding the preciousness of search for knowledge for its own sake, nor will it forget the comments of Professor Lüst, when UNESCO’s counsels are sought on science policy for developing countries. ■



41. Albert Einstein

22

The Nature of the
"Ultimate" Explanation in Physics

Experiment alone can decide on truth. ... But the axiomatic basis of Physics cannot be extracted from experiment.

Albert Einstein,
Herbert Spencer Lecture, June 1938

All science – physics in particular – is concerned with discovering *why* things happen as they do. The *whys* so adduced must clearly be “deeper”, more universal, more axiomatic, and less susceptible to direct experimental testing, than the immediate phenomena we seek to explain. And it is so well-known, that it is the *whys* of one generation which are often the points of departure for the next, to whom the earlier *whys* can appear subjective, conditioned by “unscientific” thinking, even wrong. The glory of science is that this notwithstanding, we often arrive at correct predictions – at least to the extent of the experimental accuracies achievable and often better. I wish to speak about this continuing, ever-sharpening process about the *whys* of physics in the context of the fundamental unification of physical forces on which our generation is engaged.

I can summarize my remarks in terms of three propositions:

- 1) The physics of the last century ascribed its deeper *whys* to an all-pervading mechanical aether. Einstein killed this aether, but he substituted for it, something terribly close in spirit – a dynamical space-time manifold. Following Einstein, the deepest *whys* of today’s physics are to be found as manifestations of what we choose to assume as the basic attributes of the space-time manifold.
- 2) So far as dynamics is concerned, our final court of appeal if all else fails, is the Bootstrap mechanism, the principle of self-consistency of the Universe. This principle may be traced back to the teleological dictum of Leibnitz – so savagely satirized by Voltaire in *Candide* – “The Universe is as it is for what else could it be.”
- 3) And finally, there are the Laws of Impotence – so named by Max Born – which all *whys* must respect. These laws of impotence – the glory of the physics of the 20th century – consist of not-to-be-questioned admonitions like: thou shalt

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not conceive of velocities greater than that of light, to transmit signals; thou shalt quantize angular momentum in units of the Planck's constant (h).

There are other requirements governing the desirable *whys*, like economy of concepts and simplicity (Occam's Razor), like eschewing of over-subtlety, like beauty of the mathematics to be used (which somehow appears linked with its unreasonable efficacy). But these are well-known ideas and do not need elaboration.

To illustrate my remarks, and in particular the questioning by one generation of *whys* which led the generation before to (relative) truth, consider the classic example of the laws of planetary orbits and celestial gravity theory, associated with the names of Kepler, Newton and Einstein.

Kepler, the first man to give a quantitative description of laws of planetary motion describes thus how he was led to their discovery.

"God reflected on the difference between the curved and the straight and preferred the nobility of the curve."

"Among bodies, omit ... the irregular ones, and only retain those whose faces are equal in side and in angle. There remain five regular bodies of the Greeks: cube, pyramid, dodecahedron, icosahedron and octahedron ... If the five bodies be fitted into one another and if circles be described both inside and outside all of them, then we obtain precisely the number six of circles. ... Copernicus has taken just six orbits of this kind, pairs of which precisely related by the fact that those five bodies fit most perfectly into them."

Would this type of reasoning be considered "scientific" today?¹

Kepler described Copernicus as a "blind man feeling his way with a staff." It must have been this act of hubris, which in turn had its nemesis in K  estler's description of Kepler as a "sleep-walker".

Kepler was followed by Newton, who washed his hands of the entire search for *why*; "But hitherto I have not been able to discover the cause of ... gravity from phenomena and I frame no hypotheses ... Hypothesis ... has no place in experimental philosophy."

On this attitude of Newton, Einstein had this to say: "We now realize with special clarity, how much in error are those theorists who believe that theory comes inductively from experiment. Even the great Newton could not free himself from this error (Hypotheses non fingo)."

But had Newton built no hypotheses into his gravity theory? According to Einstein, he had. This was the hypothesis that gravitational charge (m) which

¹ Before we dismiss Kepler's reasoning, reflect on our own generation's partiality for the eight-fold way, for the exceptional Lie groups as candidates for symmetry groups in particle physics, stemming as this partiality usually does from the mathematical "nobility" of these particular constructs!

occurs in Newton's Force Law ($F = \frac{m_1 m_2}{r^2}$) exactly equals inertial mass – the quantity of matter contained in the bodies which mutually attract. This is the so-called Equivalence Principle.

To see the force of Einstein's remark about Newton's assumption of the equality of gravitational charge with inertial mass, consider a hydrogen atom, which consists of a proton and an electron. In making up the atom, the electron and the proton attract each other both electrically as well as gravitationally. The inertial mass of the atom equals proton's mass plus electron's mass minus the electrical, as well as the gravitational, binding energies. The ratio of the summed masses of the proton and the electron to the two varieties of binding energies is of the order $1:10^{-8}:10^{-47}$. Now, Evötvös (in the nineteenth century) in his celebrated torsion experiment, had in fact demonstrated that gravitational charge does equal inertial mass to the extent that, for the hydrogen atom for example, the electrical binding energy ($10^{-8}:1$) contributes equally to both. But what about the gravitational binding energy? Does the tiny relative number (10^{-47}); – ascribable to gravitational binding – also affect inertial mass and gravitational charge equally? What would Newton say?

Einstein's own answer was unambiguous. His *whys* for the existence of the gravitational force ascribes this force to space-time dynamics, to the curvature of the four dimensional space-time. His theory incorporates a "strong equivalence" of gravitational charge with inertial mass. But there were rival theories – like those of Brans-Dicke's extension of Einstein's – which denied this equivalence so far as the gravitational binding-energy is concerned. According to these theories, a part of this relative 10^{-47} would not show up in the gravitational charge.

The issue between Einstein and Brans-Dicke was joined, in March 1976, in two beautiful experiments, independently carried out by two teams; one led by Shapiro, the other by Dicke himself. These epic experiments consisted of measuring the mean (Kepler) positions of the earth and the moon to ± 30 cm through lunar laser ranging measurements. For heavenly test bodies as massive as these, the relative ratio of the gravitational binding energy to the total mass is in excess of $10^{-12}:1$ (and not the miserable, unmeasurable ratio $10^{-47}:1$ obtaining for the hydrogen atom).

To nobody's surprise – except perhaps to Dicke's – Einstein's strong equivalence principle proved to be correct. Dicke's own theory must be discarded, at least to all reasonable values of a new, adjustable parameter in his theory.²

² Notice, like old soldiers, theories never die; they simply fade away. Thus one could still save Brans-Dicke's theory, but only by assuming an outrageous value for this adjustable parameter. Other phenomena would then be affected but they are (hitherto) untestable.

To summarize, Kepler, Newton and Einstein each started with a different *why* for broadly the same set of phenomena. (To be more precise, Newton disclaimed any attempt at formulating a *why* for gravity theory – even though he apparently did build into it an equivalence hypothesis, justified later by Einstein's totally different approach.) Each theory gave predictions commensurate and better than the accuracies of the experiments then possible. However, at present, Einstein's approach remains the deepest – and the most accurately predictive – that we know of for explaining the existence – the *raison behind* – one of Nature's fundamental forces (gravity). Will this forever be the case? Will this theory need modifications, extensions, become part of a bigger whole; will it even have to be discarded altogether, together with all its axiomatic substructure?

Einstein believed that the discovery of the deep *why*, underlying the other forces of nature will also follow the pattern of "geometrization" of gravity that he had given to physics. Before I consider this, let me take one more example of differing styles of the offered *whys* at different epochs of physics. The example is from one of the other fundamental forces of Nature – electromagnetism. Maxwell, you may recall, predicted the existence of the electromagnetic radiation on the basis of the "displacement current" which he invented. This is one of the greatest feats of inventive discovery man has ever made – a discovery with few parallels, in the change it brought about the world we live in. Today an A-level student would demonstrate for you the necessity of a "displacement current" from the conservation law of electric charge. But Maxwell, himself, went through a tortuous – and what today might be considered an untenable – deduction based on a mechanical model of the aether. In Einstein's phrase, "(This) great change (was) brought about by Faraday, Maxwell and Hertz – as a matter of fact, half-consciously, and against their will – (because) all three of them, throughout their lives considered themselves adherents of the mechanical theory (of the aether)." Notwithstanding this, does anyone here tonight dare feel superior to Maxwell? Even after what I just quoted from Einstein, listen to his reverence for Maxwell: "Imagine Maxwell's feelings when the differential equations he had formulated proved to him that the electromagnetic fields spread in the form of polarized waves and with the speed of light. To few men in the world has such an experience been vouchsafed."

Consider now the forces of electromagnetism, and the new nuclear forces, weak and strong, responsible for radioactivity phenomena and for fission and fusion respectively. Recently, theory suggested and experiment confirmed that the weak nuclear force combines with electromagnetism – just as magnetism combined with electricity in the hands of Faraday and Maxwell a century ago –

into one single, all embracing *electroweak* force. The secret of this unification³ lay in the extension of the so-called gauge ideas (well-known in electromagnetism) to the weak nuclear force. The characteristic of a gauge force is that such forces are proportional to the "charges" carried by the particles (e.g., $F = \frac{e_1 e_2}{r^2}$ for electromagnetism, $F = \frac{m_1 m_2}{r^2}$ for gravity).

What has been shown is that analogous to the electric charge, there exist three weak charges which determine the strength of the weak nuclear force and that these three charges – together with the electric – form four components of a "single" entity, each component transformable one into the other, through the operations of the group structure $SU(2) \times U(1)$ acting on an "internal symmetry space". I shall attempt to explain what I mean, more humanly, in a moment. But to complete the story: The future theoretical expectation is that the strong nuclear force is also a gauge force and the corresponding strong nuclear charges will eventually unite with the electroweak charges to make up a single entity, belonging to a still larger "internal symmetry group", of which the electroweak $SU(2) \times U(1)$ is a part.⁴ From the concept of the electroweak force we shall, we hope, progress soon to the concept of a unified *electro-nuclear* force, comprising electromagnetism as well as the two types of the nuclear force.

I have used the word "internal symmetry space" to designate that mysterious something which provides the present *why* for these unified gauge theories. Charges – electric, weak-nuclear, strong-nuclear – is a manifestation of the existence of an "internal" symmetry structure and of the postulated symmetries of laws of physics for rotations and other transformation in this mysterious internal space. The analogy of the internal space is with the familiar space-time.

A crucial role in the demonstration of this electroweak unification was played by the ideas of "spontaneous" symmetry breaking. To motivate these, one has to invoke self-consistency (my second proposition, see first paragraph in this chapter) and to build in a special type of symmetrical potential into the structure of the theory – a potential, which (surprisingly enough) yields solutions with less symmetry than what we started from. This potential should guarantee that the weak nuclear force remains short-range as observed, without affecting the long-range character of the electromagnetic force. There is a welcome price which one pays for inventing such a potential; one predicts the existence of a hitherto undetected particle – the so-called Higgs particle – which is currently being searched for. This particle is welcome, for its existence would show that we are on the right track. It is this sort of quantitative prediction, which distinguishes our use and our version of the self-consistency principle in physics, from empty philosophizing.

Experiments to demonstrate this have just gone underway with Brookhaven-Irvine-Wisconsin and Milan-Turin-CERN-University College-Oxford collaborations. These are experiments designed to demonstrate that the proton is unstable with a half-life of the order of 10^{30} years. Hitherto the proton has been believed to be stable. Compare 10^{30} years with the unmentionably tiny life of the Universe – of the order of 10^{10} years.

And the analogy of the electric and nuclear charges is with the gravitational charge – the inertial mass – which is associated with the translation-symmetry of the four-dimensional space-time⁵ continuum.

The question which arose in the nineteen-thirties when “internal symmetry spaces” were first invented by Heisenberg and Kemmer and which has become more and more insistent with the success of gauge ideas is this: Are these “internal spaces” purely mathematical constructs or do they represent realistic adjuncts to the four-dimensional space-time we are familiar with.

To take one example, one of the attempts currently being made is to describe physics in all 11-dimensional space-time. Of the 11-dimensions, four are the familiar space-time dimensions whose curvature is related to gravity and the other seven dimensions correspond to an internal symmetry space. In the theory advanced, the seven dimensions curled in upon themselves 10^{-43} sec after the Big Bang, attaining a size of the order of 10^{-33} cm and no more. We live on a cylinder in 11-dimensional space, our major source of sensory apprehension of these extra dimensions being the existence of charges – electric, weak-nuclear and strong-nuclear and the corresponding forces as manifestations of their curvature. Thus will Einstein’s final dream (with which he lived for thirty-five years of uniting gravity) with the other (electronuclear) forces be eventually realized.

Exciting idea, which may or may not work quantitatively. But one question already arises: why the difference between the four familiar space-time dimensions and the seven internal ones? Why may the one lot curl in upon themselves, while the other does not? For the present, we shall make this plausible through the self-consistency principle; we shall invent a potential which will guarantee this as the only stable self-consistent dynamical system, which can exist. There will be subtle physical consequences of this perhaps, in the form of remnants, like the black body radiation, which was a remnant of the Big Bang. We shall search for these. Even if we find them, the next generation may perhaps question this entire mode of thought – particularly if a small discrepancy with our predictions is detected – and the cycle of questioning and answering might start all over again. Even today, an obvious question would be: Why eleven dimensions; why not a wholesome number, like thirteen? Or is this once again, due to the operation of the Bootstrap, the self-consistency principle?

There is an alternative suggestion to these extra dimensions, which seeks to explain charges (other than gravitational) within the context of no more than a

⁵ Translation-symmetry is the statement that the laws of physics are independent of the location of where an experiment to test them is performed. This is one example of symmetry, which we choose to ascribe to space-time structure; cf. the first proposition of paragraph 1. The experimental consequence of this assumed symmetry is the empirically testable conservation of energy and momentum.

conventional four-dimensional space-time. This suggestion, due to Wheeler, Schemberg and Hawking, does not add in new dimensions; it instead associates the electric and the nuclear charges to space-time topology – space-time Gruyere-slices, wormholes of the granular size of the order of 10^{-33} cm. The idea is attractive. Topology, you may recall, is concerned with “global” aspects as contrasted with the “differential” aspects of the present tradition in physics. It thus represents a real break with the past. Unfortunately – and I say this deliberately and ungratefully, in order to provoke some of my friends, in this audience – my own feeling is that the mathematics of topology, in respect of what we need, has not progressed beyond the Möbius strip and the Klein-bottle. Topology – as a language for physics is not yet capable of supporting the edifice the physicist may wish to erect on it. Could it be that our generation is defeated by the lack of development of a necessary mathematical discipline in a direction that we need? This has never happened before in the history of physics, but on this note, I would like to leave you to ponder on the deeper *whys*, appropriate to the physics of today – and tomorrow. ▮



42. Herbert Spencer



43. Johannes Kepler



44. Isaac Newton



45. Albert Einstein



46. Werner Heisenberg



47. Stephen Hawking

23

Expatriate Nationals and Promotion of Education and Research in Developing Countries

I am deeply honored and appreciate the opportunity given to me to speak to this distinguished audience today. For this, I am indebted to the Canadian Development Agency, the University of Ottawa, and the Canprep Organization.

Canada is a major world power, which, in the words of its Foreign Minister, accepts internationalism as one of its foremost national values. Canada is near to us in the developing world because like us, its prosperity depends on primary commodities – agricultural products, metals, minerals and fuel, which constitute 46% of its total exports. And Canada is one of the few countries where scientific research is accorded a high priority at the national, as well as the international level. The support given to sciences by CIDA amply testifies to this. Also, there is nothing elsewhere like the prestigious International Development Research Centre created by men of vision like Maurice Strong, David Hopper and now Ivan Head, with its remarkable record of achievements in stimulating scientific and technological research in the developing world.

I am honored to speak to this forum, which has been organized by expatriates. What makes me particularly happy is that, besides the active encouragement of their host country (whose life they enrich), the expatriates are also being encouraged by their own country of origin.

Psychologically, an expatriate, particularly in the first generation, always feels passionately and possessively, even neurotically, for his country of origin. This is because to make oneself an exile from one's country, to cut off one's personal and cultural roots, is a traumatic experience. One is always keen that those adverse circumstances, which forced one to make that agonizing choice, are eliminated.

But the fact that an expatriate's country of origin should be willing to accept his professional help and that the United Nation's Agencies, like UNDP should organize this, through programs like TOKTEN, is a new feature of the international climate, which till recently did not obtain. Not long ago an expatriate was essentially an outcast so far as official attitudes were concerned. His economic help may have been welcomed, but by and large, not his active

Excerpts from the lecture delivered under the auspices of the Canadian Association for the Promotion of Research and Education in Pakistan and the Institute for International Development and Cooperation of the University of Ottawa, Canada, September 23, 1982.

involvement in the nation-building process in his country of origin. Personally, I was one of those fortunate few who, though an expatriate from 1954 in the United Kingdom and Italy, found opportunities for involvement, not only in Pakistan's own scientific development, but also, with Pakistan's help, in international ventures designed towards scientific development of the developing world in general. Clearly you have invited me (for its morals) to give you one expatriate's story, of help he could render to his country's science and with his country's help to science in the developing world in general.

However, before I do this, let me state my major thesis, which I wish to lead up to through the story of my personal struggles. In presenting this thesis I am not speaking of either Canada or Pakistan. My remarks are general and I hope they will not be misunderstood. My thesis is simply this: the developing world, in spite of its recent realization that science and technology are the sustenance, and in the long run, its only hope, has taken to it only as a marginal activity. And so, unfortunately, also have the national aid-giving agencies, as well as the scientific and technical agencies of the United Nations. Donors and donees as well as prestigious Commissions (like the Brandt Commission) speak of nothing else but technology transfer as if that is all that is involved. By and large, very few realize that for long-term effectiveness, technology transfers must always be preceded by science transfers; that the science of today is the technology of the future; that science transfer is affected by and to communities of scientists; that these communities need stability, long-term commitment, generous patronage, self-governance and free international contacts to grow. Such communities must be allowed to grow to critical sizes in the developing countries, they must be visibly strong and, most crucially, they must be allowed to play a role in nation-building as equal partners to the professional planners and the economists. I wish to make a plea to the development agencies everywhere, that they must take a long-term attitude to the growth of science – both basic and applied – in the developing countries. Through the immense leverage they can exert, they must ensure that adequate infrastructure is built in the developing countries they help, and that the scientific communities there are enabled and allowed to play their rightful roles, both in building this infrastructure, as well as in the process of development. To highlight the role which Agencies like the World Bank or IMF can play, consider the following quote from a recent biography of the World Bank by E.S. Mason and R.E. Asher: "UNESCO had been providing sensible advice on educational planning for years, before the Bank entered the field. ... Sometimes, some parts of this advice were accepted. But there was a notable increase in attention given to educational planning when it became clear that projects ... had some chance of being financed."

There is no question today that the developing world is in the throes of a disastrous short-term crisis – the crisis of economic bankruptcy. The poorer three-quarters of mankind are increasing their indebtedness to the richer nations by one hundred billion dollars a year as was starkly pointed out at the forum of

the World Bank and the IMF at their recent meetings at Toronto. Soon the poorest amongst us will not be able to borrow or draw on our reserves. In the words of the prestigious London *Economist*, "these people will simply starve".

But this short-term crisis is only a part of a longer-term crisis. Our world is terribly unbalanced in income and in consumption. At least three-quarters of the world's income, three-quarters of its investment, and almost all of the world's research are concentrated in the hands of a quarter of its people. They consume 78% of its major minerals, and for armaments alone, as much as the rest of the world combined. [...]

In 1961, I was visiting M.I.T. for its centennial celebrations. The Science for Developing Countries Session was chaired by Professor J. Wiesner, who had recently been appointed President Kennedy's Science Adviser. Before me the speaker was the eminent physicist Professor P.M.S. Blackett, the Head of my Department at Imperial College and the father of operational research during World War II. Blackett's thesis in his speech was: "All science and all the technology which the developing world needs is available in the world supermarket of science. Go and purchase what you wish." Following Blackett, I respectfully said his blanket assertion was false in the sense that no degree of buying could ensure one could get what one needs. The developing countries must invest in high-level manpower, if only to examine what is available with some understanding and to build upon it. And then I gave the example of Pakistan's salinity and waterlogging problem. Wiesner was mightily interested; he came to me after the meeting. He said he would like to help. He persuaded President Kennedy to assemble a team of university scientists, hydrologists, agriculturists and engineers, led by Roger Revelle, to advise on Pakistan's waterlogging and salinity. This team visited Pakistan and suggested continuous pumping out of saline water to lower the water table, but with the important caveat that the pumping operation must be simultaneous over a contiguous area as large as a million acres – otherwise the quantity of water seeping in from the periphery would exceed the quantities pumped out. Pumping had been tried on parcels of land smaller than one million acres, but had proved ineffective. Some of you may recall that Blackett himself during the last war was called upon to suggest to the British Admiralty whether merchant ships should cross the Atlantic in a few large convoys or small ones – given that the number of available destroyers protecting against enemy submarines was fixed. Noting that ratio of area to circumference maximizes with large radius, Blackett had suggested fewer large convoys rather than many small ones. The Revelle team's suggestion for Pakistan was a remark equally simple and it equally simply worked.

I had accompanied Revelle's team; I was insistent that the team recommend the creation of a permanent – if possible an international – research center for waterlogging and salinity in Pakistan to monitor the problem continuously.

Unfortunately Revelle made no such recommendation; nor did the Pakistan Government accept this suggestion. The result could be foreseen. Twenty years after Revelle, the configuration of the water table has dynamically changed. The parameters have shifted. Dr. Amir Muhammad Khan, as Chairman of the Agricultural Research Council, is, twenty years later, calling for international help for the self-same research center. I hope and pray, this time his efforts meet with success. And this need for the well-trying institutional arrangement of a center for waterlogging and salinity in Pakistan brings me back to the question of whether such centers should be internationally run. The experience in agriculture, with the Rockefeller-Ford-World Bank run CGIAR Institutes has amply confirmed that there is no question but that the developing world needs international institutions of this type on the applied side like the Wheat and Rice Institutes. Likewise, the Trieste experience on the physics side. Such internationally funded, internationally run centers guarantee stability, guarantee standards, guarantee keeping abreast of new ideas, guarantee the transfer of science and technology by the very men who created it. Such men will come to work at the centers for idealistic reasons, as we have experienced at Trieste. The Trieste example is now being copied with the recent setting up of an International Centre on Mathematics at Nice by France; by the creation of an International Centre for Physics in Colombia, specializing in photo-voltaic; by an Institute of Fundamental Studies in Colombo, specializing possibly in space sciences; by a Centre for energy in Spain; by a Centre on mineral and mining technology in Peru and an international Centre for hydrology, neurobiology and petroleum technology in Venezuela. Some weeks ago I had the pleasure of receiving in Trieste the representative of Quebec, Professor Jean Martucci, who is located in Rome. He was in Trieste to find out more about my Centre, since the Government of Quebec is interested in hosting the International Centre on Biotechnology, which the United Nations Industrial Development Organization is proposing to create on our model. This information was music to my ears. There is no question that such an institution would benefit the developing countries in this fast-changing subject. It would also clearly benefit the country, which was hosting it. The question about these International Centres always is: who should pay for them?

In science, as in other spheres, this world of ours is divided between the rich and the poor. The richer half – the industrial North and the centrally managed part of humanity – with an income of five trillion dollars, spends 2% of this – some one hundred billion dollars – on non-military science and development research. The remaining half of mankind – the poorer South, with one-fifth of this income of around one trillion dollars – spend no more than two billion dollars on science and technology. On the percentage norms of the richer countries, we would be spending ten times more – some twenty billion. At the United Nations-run Vienna Conference on Science and Technology held in 1979, the poorer nations pleaded for international funds to increase their present expenditures of two billion to four billion. They obtained promises of half of this.

However when it came to actually creating the so-called Interim Fund for Science and Technology at the United Nations, it received a total subvention of forty-eight million dollars from all nations. The major donors were the Governments of Italy, Norway, Sweden, the Netherlands, the USA and Switzerland. From two billion to forty-eight million for all science and technology in the United Nations for all developing countries!

I would like to conclude with two appeals.

Since some of my listeners here are the leaders from developing countries, let me address them first. In the end, science and technology amongst us is our responsibility. Speaking as one of them, let me say this: The growth of science follows a well-tried pattern, invented in the West, and successfully copied by Japan and the USSR, a pattern now being copied by the larger of the developing countries like China, Brazil and India. No patchy applications of science and technology, no patchy transfers of technology will make up for it. We in the developing world must begin to realize that we must go the whole cycle. Our men of science, including the expatriates, are a precious asset. Our nations must learn to prize them, give them opportunities, responsibilities for the scientific and technological development of their own countries. At present, even the small numbers that exist, are underutilized. However, the goal must remain, firstly to increase their numbers – in many cases tenfold – and secondly, to increase the two billion internally spent on science and technology to twenty billion. Science is not cheap. But the basic science of today is tomorrow's application. In the conditions of today, technology cannot flourish without science flourishing at the same time. This was dramatically emphasized to me by a Turkish physicist from the University of Samsun who recalled that Sultan Selim III did introduce studies of algebra, trigonometry, mechanics, ballistics and metallurgy in Turkey already as long ago as 1799 creating special schools for these disciplines with French and Swedish teachers. His purpose was to modernize the army and rival European advances in gun-foundries. Since there was no corresponding emphasis on research in these subjects and since the scholarly establishment in the madrassahs who called themselves scientists, 'alims, had nothing but contempt for these new technological schools – "funun", Turkey did not succeed. In the long run, in the conditions of today, technology unsupported by science, simply cannot flourish.

My second appeal is to the aid-giving agencies and the international organizations.

A world so divided between the haves and the have-nots of science and technology cannot endure: at present an International Centre for Theoretical Physics, with a present budget of four million, is all that is internationally available for physics for ninety developing countries. Compare this with European joint projects involving physics alone, of half a billion dollars annually. Compare this with the cost of one nuclear submarine – 3.5 billion dollars. One

thousand centers like Trieste could flourish for one year for the price of one such submersible and at present there are two hundred and fifty nuclear submarines in the world's oceans. Somehow, somewhere a break must come.

But even with the funds that the aid-giving agencies do disburse, could one hope for an earmarking, for example of 10% of the total funds, for science and technology, with one-half of this devoted to building up the basic scientific infrastructure and manpower in our countries? This would have to be on a continuing, and not a year-to-year basis, because science needs continuous involvement.

One of the modalities for this – and a well-tried modality – is the creation of an International Foundation for Science for giving grants to individual scientists in the developing countries. An International Science Foundation with these aims was in fact created at the suggestion of Roger Revelle, Pierre Auger, Robert Marshak and myself in 1972 in Stockholm. This Foundation is currently supported by Sweden, Canada, USA, Federal Republic of Germany, France, Australia, the Netherlands, Belgium, Nigeria, Norway and Switzerland. Its funds are given for research in the areas of aquaculture, animal production, rural technology and natural products, to individual researchers in developing countries, in grants not exceeding ten thousand dollars. Unfortunately the total funds at the disposal of this Foundation are two million dollars only. And it does not cover other natural sciences. In this context, and with the Brandt Commission's recommendations on technology transfer in mind, in August 1981 I wrote the following letter to Prime Minister Trudeau (and also to all the other attending Heads of State), just before the Cancun Summit:

My dear Prime Minister, I understand the technology transfer, with emphasis on problems of energy, will be one of the items for discussion at the forthcoming North-South Heads of States meeting in Mexico. Unhappily, most developing countries need help in building up scientific infrastructure at all levels and Science Transfer must accompany technology transfer if the latter has to take root in our countries. The scientific community in the North can, and I am sure will, be willing to help in building up the corresponding community in the South, provided it is mobilized for this.

I would therefore like to suggest the creation of a North-South Science Foundation to build up a movement towards Science Transfer, with funds at its disposal of an order at least similar to those, for example, disbursed by the Ford Foundation (between one hundred and two hundred million dollars a year). This Foundation should be run by the world's scientific community for research and training for research, in those basic sciences in developing countries which relate to technology transfer.

On the Prime Minister's behalf I received the following reply:

Your proposal for a North-South Science Foundation is an interesting concept. Canada recognizes the importance of science and technology transfers to developing countries, and the need for indigenous scientific and technological capabilities if these transfers are to be successfully exploited. As you are no doubt aware, the Canadian Government in 1970 established the International Development Research Centre (IDRC) specifically to address these issues. The IDRC has shared your view that the most effective way to provide developing countries with science and technology best suited to their needs is to enable those countries to carry out their own research, to train their own scientists in the process, and to share the resulting knowledge as widely as possible. The Canadian Government is committed to substantial increases in IDRC funding.

I am looking forward to discussing with IDRC the flowering of these ideas and the expatriates' possible role in their realization. ■

24

The Fusion of Cultures in Spain

You have done me a great honor today. Since it is a personal honor which you have bestowed on me, forgive me if I respond in a personal manner.

I was eight years of age when I started to dream about Spain. I was given a copy of the *Tales of Alhambra* by Washington Irving in translation in my native language – Urdu. It was the quality of magic which suffused the tales which captured me – the magic which, according to Irving, has held the fortress of Alhambra under a spell so that in defiance of storms and earthquakes, while all neighboring buildings fell to ruins, the palace and the fortress survive. It is a magic spell which will last till such time as that gigantic hand which is engraved on the vestibule on the keystone of the portal descends to grasp the gigantic key, engraved below the hand.

I visited Alhambra for the first time in 1955 and then again in 1981. If anything, the feeling of magic has enhanced for me with each visit. Added to the vision of Alhambra's grace and its incredible beauty, has been the magic of Spain's landscape and particularly the landscape around Granada – so similar in aspect to my country's own North-West Frontier – a landscape "consisting of chains of mountains destitute of shrubs, mottled with variegated marbles and granites ... yet with verdant valleys lying in their midst, where the desert and the garden strive for mastery and the very rock is, as it were, compelled to yield the fig, the orange and the citron and to flourish with the myrtle and the rose."

During 1981 I also visited Madrid, Toledo, Sigüenza and Cordoba. And then I realized that this quality of magic was not confined to Alhambra alone. It suffused the whole landscape and the people and it derived from a unique mixing of Christian, Arab-Islamic and Jewish cultures which Spain achieved during the past centuries. Its reminding in these troubled days can be one of Spain's greatest gifts to mankind.

For me as a scientist, the significance of this unique fusion of cultures in Spain lies in that it led to one of the most important episodes of internationalization of sciences in human history. This internationalization came

Address on the occasion of Honoris Causa, Universidad Complutense de Madrid, January 28, 1983.

to its highest flowering in the Toledo school of learning and research in the 12th and 13th centuries. And it was the inspiration of this school which led to the founding of an International Center for Theoretical Physics at Trieste in Italy. Through this Centre, I have been privileged to work for Spanish science as well as for science in the developing countries.

As you know, Toledo was a part of Arab Spain for more than three and a half centuries – from 712 to 1085. It was a center of Arab learning and scholarship. In 1085, Toledo was conquered by Alfonso the VI of Leon and Castile. Toledo, at that time, had a mixed population of Christians, Arabo-Iberians, Jews, Mozarabs and Mudejars, who felt as one people, notwithstanding the differences of their languages, faiths, and cultures. The conquest of Toledo by Alfonso gave it a new role – as a center for direct transmission of knowledge to Western Europe. This role was encouraged by the wise Archbishop Raymond I (1126-1151). He gathered around him a school of translators, translating from the scientific texts then available in Arabic in Toledo and in the rest of Spain. Arabic was the language of science, with three hundred years tradition of scientific creativity behind it. The translations were made from Arabic to Castilian and then from Castilian to Latin. The greatest of these translators were Domingo Gaudisalvo and John of Seville. With them joined men from other parts of Europe, among them, Herman the Dalmatian, and Robert of Chester who translated the Holy Qur'an, the algebra of Al-Khwarizmi, besides the latest Arabic texts on medicine, physics, optics, chemistry, mathematics, geography, philosophy and even biology. In addition, there were translations from Arabic into Hebrew by Abraham ibn Ezra and Abraham Bar Hiyya. These Jewish translators did for their brothers in the rest of Europe (who unlike the Spanish Jews, were ignorant of Arabic) exactly what Spanish translators were doing for Europe in general. Thus was the tradition of Jewish scholarship modernized in sciences, at that epoch.

A generation after this, in the early thirteenth century, to Spain came the Englishman Alfred Sareshel, and the Scotsman, Michael the Scot. The story of Michael the Scot has always fascinated me; as his countryman Sir Walter Scott reminds us, Michael the Scot acquired the reputation of a wizard.

A wizard of such dreaded fame,
That when in Salamanca's cave,
He lifted his magic wand to wave,
The bells would ring in Notre Dame.

To me Michael has been the symbol of a scholar from a then developing country who left his native glens to travel south to Toledo as part of a talent drain. [...]

As I said before, Toledo's school, representing as it did the finest synthesis of Arabic, Greek, Latin and Hebrew scholarship, was one of the most memorable of

international assays in scientific collaboration. To Toledo came scholars not only from the rich countries of the East, but also from developing lands of the West like Scotland. Then, as now, there were obstacles to this international scientific concourse, with an economic and intellectual disparity between different parts of the world. Men like Michael the Scot, were singularities. They did not represent any flourishing school of learning in their own countries.

Scot enriched European scholarship making available to it the treasures, not only of Aristotle and other Greeks, translated from Arabic, but also the newer sciences created by Ibero-Arab scientists in the South of Spain. For, from the 9th century onwards, South Spain was not just an outpost of scientific culture which flourished in the Middle East, it was in the forefront of scientific creativity. The center of this creativity was Cordoba where the Caliph Al-Haken II (961-971) had amassed a library collection of 400,000 manuscripts. During his reign flourished Abul Qasim (Albucasis), the great surgeon, and the Jewish Physicians Hasdai Ibn Shaprut and Ibn Gabriel. The medical tradition built by these great Spanish men of medicine, flourished during the next hundred years, maintained by the Ibn-Zuhr (Avenzoar) family. Ibn-Zuhr lived in Seville where he was born in 1090 and died in 1162. His three books, *Kitab-al-Iqtisal* (the book of therapeutics and hygiene), *Kitab-al-Taisir* (the book of prescriptions), and *Kitab-al-Aghdiya* (the book of diets), in their Latin translations, maintained their influence on European medicine until the 17th century. But the greatest name in medical tradition was that of Ibn-Rushd (Averroes) who was born in Cordoba in 1126. Averroes is today more known for his philosophy and his influence on the theological thinking of Thomas Aquinas. But in his day, his *Kitab al-Kulliyat fil-Tibb* was the great medical encyclopedia. And then there was Ibn Rushd's near contemporary, the greatest Jewish physician and philosopher, Maimonides (Musa ibn Maimun), who was born in Cordoba in 1135 and died in Cairo in 1204, as a court physician of the great Saladin. Some thirty years later, Spain produced one of the world's greatest botanist and pharmacist, Ibn-Al-Baitar. The tradition of excellence in medicine continued till a hundred years later, with the work of Ibn-al-Katib (1313-1374) and his contemporary the physician Ibn-Khatimah. These two men gave the earliest account of the Black Death and deduced that its spread was due to contagion. It is no accident that Spain has remained pre-eminent in medicine, neurophysiology and surgery.

I could recount a parallel story of achievement in mathematics and astronomy. For example, in Toledo, was developed the area of sophisticated scientific instrument making. In particular in the 11th century Al-Zarqali (1029-1087) invented an improved form of Astrolabe, compiling the famous Toledan tables.

But to get back to the role of Spain and particularly Toledo, in respect of transmitting to Europe in the 12th and 13th centuries the stock of humankind's

scientific knowledge then existing in Arabic, one may, without hesitation, say that without this transmittal, there would have been no Renaissance, and perhaps no science, as we know it today. As Heaton in his *Economic History of Europe* has remarked: "If the North wanted the best in science, medicine, agriculture, industry and civilized living, it had to go to Spain to learn." And it did. Scholars from England, Scotland, Scandinavia, Germany, France, flocked to Spain to learn science. This transmittal needed a toleration of Arab scholars at Christian courts and Christian scholars at Arab courts. It needed a largeness of spirit and a security for men of science, even in time of political and military conflict. As an instance of this toleration, you may have remarked on the number of Jewish names, among those which I have mentioned, at Muslim as well as Christian courts. I have, for example, recounted the work of Abraham ibn Ezra and Abraham Bar Hiyya at the Christian court of Toledo and the work of Ibn-Gabriel, Ibn-Shaprut and Maimonides at Arab Cordoba. Is it not significant that Maimonides wrote his greatest work on Jewish theology – the *Guide to the Perplexed* – in Arabic? It was only later that it was translated into Hebrew by one of his pupils. There could be no greater tribute to the spirit of that remarkable Age in Spain.

What is the relevance of this story for today? Speaking narrowly on behalf of the developing countries, which include countries of Latin America, as well as those in Africa, the Middle and Far East, one must state that there is a basic prerequisite for this acquiring of sciences. This prerequisite is the availability and accessibility of places like Toledo for international scientific concourse where one can light a candle from a candle burning brightly there. National universities in the advanced countries used to perform this function in the 19th and early 20th centuries. I say it with sorrow, but unfortunately, opportunities for international scientific concourse at national centers of learning are shrinking with greater restrictions in the traditional countries like the UK on the acceptance of overseas scholars, particularly those from the developing countries. When I was a student at Cambridge, the University fees amounted to no more than £70 per year. In 1983, they will be £3,500 – an increase by a factor of fifty. The Toledos of yesterday are becoming hedged around, at the least by economic fences. Unless this trend is arrested, it is becoming increasingly clear that the world will need centers of science run internationally by organizations like the United Nations.

One such center, whose creation I had the privilege of suggesting to the Board of the IAEA in 1960, is the International Center at Trieste. This center was set up in 1964 and since then, we have had the privilege of welcoming some three hundred Spanish physicists to workshops for research; some as directors, others as participants. Some of whom are here in the audience today; I had the privilege of knowing them first at Trieste. ...

The Trieste model is now being copied at other places. For example, there has been set up at Nice an International Centre for Mathematics, created by the French Government. There have recently been created a Centre on Fundamental Sciences in Sri Lanka; a Centre for Physics in Colombia; a Centre in Venezuela. In 1981, I had the privilege to attend a meeting in Siguenza, where the suggestion was made to set up an International Centre for Energy Sciences which would have Spanish, English, as well as Arabic as its working languages, located perhaps in Toledo. A center like this, operating on the scientific and technological level is desperately needed by the developing world. None exists at present, in this crucial field.

To conclude, Spain, in its great past, showed humankind how a fusion of cultures can be effected; it created a civilization whose quality I can only describe, by referring once again to the magic of Alhambra and Toledo. Mankind needs to be reminded once again of this spirit of basic toleration for basic values of civilization, respected, so far as scientific scholarship is concerned, even at times of conflicts. [...] ▮



48. Honorary Degree, Aligarh Muslim University, India, 1981



49. Honorary Degree, University of Madrid, 1983

25

The Gulf University and Science in the Arab-Islamic Commonwealth

"Allah is He who made (it possible) for you (to acquire) mastery over the oceans; thus (your) craft can ply thereon, with Allah's command – Allah is He who gives you subjection over all that is in Heaven and on Earth: Herein are Allah's signs for people given to reflection." (*Al-Qur'an*, 45:12-13)

Tafakkur and Taskheer (Science and Technology)

I have quoted these verses from the Holy Qur'an for they speak of the two concepts of "Tafakkur" and "Taskheer" together in the same place.

Tafakkur is the reflection on, and discovery of, the laws of Nature (science); *taskheer* is the acquiring of mastery over Nature through technology. Both of these, throughout the ages, have been the shared urges of humankind. It is the glory of Islam that the Holy Qur'an, by repeated injunction, enjoins their pursuit as a bounden obligation on the Muslim community. And as in the verses above, there is the emphasis that *tafakkur* and *taskheer* (science and technology) are not distinct; they form parts of the same spectrum.

Following these injunctions, barely a hundred years after the Prophet's death, the Muslims had made it their task to master the then-known sciences. With feverish haste, but systematically, they translated the entire corpus of the then-known knowledge in their religious language, Arabic. Founding institutes of advanced study (*Bait-ul-Hikmas*) and prestigious universities (like the Nizamiyyah), particularly in this part of the world, acquired an ascendancy in sciences that lasted for six hundred years.

The Level of Scientific Creation in Islam

A semi-quantitative measure of this is given by George Sarton in his monumental *History of Science*. Sarton divides his story of the highest achievements in science into Ages, each lasting fifty years. With each, he associates one central figure: thus, 500-450 BC is the Age of Plato, followed by the Ages of Aristotle, Euclid, Archimedes and so on. From 750 to 1100 AD, however, it is an unbroken succession of the Ages of Jabir, Khwarizmi, Razi, Masudi, Abul-Wafa, Biruni and Omar Khayam. In those three hundred and fifty years, Arabs, Turks, Afghans and Persians – chemists, algebraists, clinicians,

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geographers, mathematicians, physicists and astronomers of the commonwealth of Islam – held the world stage of sciences. Only after 1100 AD, in Sarton's scheme, do the first Western names begin to appear; however, for another two hundred and fifty years, they only share the honors with men of Islam like Ibn Rūshd, Nasir-ud-Din Tusi and Ibn Nafis.

To mark the level of this achievement and to emphasize the originality and caliber of science in Islam, I shall take my own subject of physics as an example. Contrary to the views of the Greeks – and I quote from H.J.J. Winter's *Eastern Science* – "Ibn Sina (Avicenna, 980-1037 AD) regarded light as an emission by the luminous sources of particles traveling at finite speed; he understood the nature of heat and force and motion." His contemporary, one of the greatest physicists of all time, Ibn al-Haitham (Al-Hazen, 965-1039 AD), who started work at nearby Basrah and then migrated to Egypt, made experimental contributions of the highest order in optics and "enunciated that a ray of light, in passing through a medium, takes the path which is easier and quicker". In this he was anticipating Fermat's Principle of Least Time by many centuries. He enunciated the law of inertia, later to become Newton's first law of motion, and described the process of refraction in mechanical terms by considering the movement of "particles of light" as they passed through the surface of separation of two media, in accordance with the rectangle law of forces (an approach later rediscovered and elaborated by Newton).

Al-Khazini of Merv (12th century AD) in a remarkable treatise entitled *The Book of the Balance of Wisdom* worked out a theory of universal gravity directed towards the center of the earth; he was also responsible for the assumption that air has weight and for original works on capillarity. Qutb-ud-Din al-Shirazi (1236-1311 AD) and his pupil Kamal-ud-Din gave the first explanation of the rainbow, stated that the speed of light is in inverse ratio to the optical, rather than the material, density of the medium, and that hyperboloidal lenses avoid spherical aberration.

In assessing this work, let us not forget that most of these men were only part-time physicists. They were universalists – physicians, astronomers, lexicographers, poets and even theologians at the same time.

In this recital, I have not mentioned Al-Biruni (973-1048 AD) who, working in Afghanistan, was a great experimenter like his contemporary, Al-Hazen. He was as modern and as unmedieval in outlook as Galileo, six centuries later, with whom he shares the independent (prior) discovery of the so-called Galilean invariance of the laws of Nature – the liberating statement that the same Laws of Physics apply here on earth and on the starry-orbs in the heavens.

I have mentioned some of the great new ideas in physics due to the Muslims. But like all science, the bulk of the scientific work in Islam is not a record of what these universal luminaries did; it is painstaking, slow accumulation of data, supplemented with critical examination, exposition and commentary on the work of their peers. As Brian Stock has remarked in his perceptive review *Science and Technology and Economic Progress in the Early Middle Ages*, "The most

remarkable feature is that science in one form or another was the part-time or full-time occupation of so large a number of intellectuals." Consider in this respect the following extract from the entry under "Euclid" in Al-Nadim's *Catalogue of Sciences*, the *Fihrist*: "(The Elements) was twice translated by Al-Hajjaj Ibn Yusuf Ibn Matar: one translation, the first, is known under the name of *Harunian*, while the other carries the label *Ma'munian* and is the one to be relied and depended on. Furthermore, Ishaq Ibn Hunayn also translated the work, a translation in turn revised by Thabit Ibn Qurra Al-Harrani. Moreover, Abu 'Uthman Al-Dimashqi translated several books of this same work; I have seen the tenth in Mosul, in the library of Ali Ibn Ahmad Al-Imarani (one of whose pupils was Abdul-Saqr Al-Qabisi, who in turn in our time lectures on the *Almagest*). Al-Nayrizi also commented upon it, as did Al-Karabisi. Further, Al-Jawhari wrote a commentary on the whole work from beginning to end. Another commentary on Book V was done by Al-Mahani. Furthermore, Abu Ja'far Al-Khazin Al-Khurasani composed a commentary on Euclid's book, as did Abul-Wafa, although the latter did not finish his. Then a man by the name of Ibn Rahiwayh Al-Rajani commented on Book X, while Abul-Qasim Al-Antaqi commented on the whole work. Further, a commentary was made by Sanad Ibn Ali, and Book X was commented upon by Abu Yusuf Al-Razi. With this meticulousness, no wonder one of the earliest scientists to worry about Euclid's axiom of parallels was Nasir-ud-din Tusi."

As Stock remarks: "Al-Nadim's catalogue is complete. ... However there is one aspect of Mathematics he omitted, this was the practical." Nadim did not say that the diffusion of Hindu-Arabic numerals and the decimal positional system was brought about by trade. Nor did he mention that Muslim mathematicians, to a much greater degree than the Greeks, interested themselves in everyday problems. Masha'allah, the noted astrologer (d. ca. 815-20 AD), was the author of a treatise on commodity prices. Abul-Wafa combined original work on Euclid and Diophantus with books bearing such titles as *What Is Necessary from Geometrical Construction for the Artisan*. In these works, the theory was old but the examples were new. One may doubt that the most refined theory penetrated commercial circles, but "commerce stimulated the theorists and oriented them towards the concrete". Such was the temper of the Islamic Society - Basic Sciences as related to their Applications to Life - *Tafakkur* and *Taskheer*. In this context, one may quote Sarton again: "The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due to the Muslims down to the 12th century."

In planning for the super-University of the Gulf States, we heard yesterday at this meeting an exposition of this new institution as a possible university of technology (taskheer). Today, I shall be emphasizing the other side of the coin: the aspects of tafakkur (science), which lie at the heart of all modern technology. I wish to emphasize that in the context of the Arab-Islamic Commonwealth of Nations, we must also give the highest priority to the creation of sciences and

wish to outline the steps we need to take, both in regard to the evolution of the super-University at Bahrain as well as outside it, if we are to regain our rightful self-respecting place among the comity of nations. The proposed University in Bahrain is rightly placed to help achieve this pre-eminence in sciences as a pre-condition for pre-eminence in technology. Just as Bahrain has successfully developed the highest traditions in sophisticated banking in a short span of time, I believe it also has the potential to develop sciences, through the establishment of centers of excellence at the proposed University. From ancient times, Bahrain has been at the crossroads of civilizations and cultures with a tradition of nurturing and toleration of new and venturesome ideas – a prerequisite for the developing of sciences.

The Present Picture of Sciences in Islamic Countries

What is the picture of science and technology in the Islamic Commonwealth? For purposes of identification, the Arab-Islamic peoples fall into six geographical regions. First and foremost are the nine countries of the Arabian Peninsula and the Gulf. The second region consists of the Arab northern tier: Syria, Jordan, Lebanon, the Palestinian West Bank and Gaza. The third region comprises Turkey, Muslim Central Asia, Iran, Afganistan and Pakistan. The fourth (most populous) region consists of Bangladesh, Malaysia, Indonesia, plus the Muslim minorities in India and China. In the fifth region are the Arab countries of North Africa, while the sixth region would comprise the non-Arab African countries. If we consider the present enrollment in scientific and technological education in the 18-23 year age group at the universities as an index of high scientific potential, the Islamic countries average 2% of the relevant age group compared to the norms of around 12% for the developed countries. A similar ratio of 1:6 prevails also in respect of GNP expenditures on scientific and technological research and development. No detailed statistics of numbers of those engaged in scientific research are available. However, in the Background Paper submitted to the first meeting of the Organization of Islamic Conference, which was held in Islamabad during May 10-13, 1983, a figure of around 45,136 research and development scientists and engineers was given for the entire Islamic world, compared to one and a half million in the USSR and four hundred thousand in Japan.

According to Zahlan, an analysis of these and similar figures reveals that so far as Physics is concerned, the Arab-Islamic community is around one-tenth in size and one-hundredth in scientific creativity in research publication, compared to the international norms. Pakistan, which is one of the most advanced Islamic countries in Physics, has nineteen universities, but only thirteen Professors of Physics, and a total of forty-two Physics PhD teachers and researchers in all its universities – this for a population of eighty million. In comparison, the corresponding numbers at one College at one University in the United Kingdom – the Imperial College of Science and Technology – are twelve Professors and one hundred researchers.

These figures are dismal; what makes them more dismal is the unfortunate fact that our scientific effort is isolated from international science. As a measure of this, it is amazing but true that with the exception of Egypt, which is a member of sixteen Unions, no other Arab or Islamic country uniformly subscribes to more than five International Scientific Unions in the diverse subjects of science. No international centers of scientific research have been created or are located within our confines; few international scientific conferences are organized there; very few of us, if living and working in our own countries, are privileged to travel to scientific institutions and meetings outside; such travel, as a rule, is considered wasteful luxury. The situation is a little better in Arab OPEC countries; it is dismal in non-Arab Islamic lands. It was this isolation, which prompted me to propose the creation of the International Centre for Theoretical Physics so that others do not make exiles of themselves if they wish to keep themselves abreast of newer developments in their subject. This Centre belongs to two United Nations Agencies – IAEA and UNESCO; some one hundred and seventy-five Arab and Muslim physicists (out of around 1000 from developing countries) are supported at the Centre every year. Of these, twenty-five are supported by the Kuwait Foundation for Science and Kuwait and Qatar Universities; the rest come with funds provided by IAEA, UNESCO or the benefactions I can secure from Italy or Sweden.

To give an outside observer's assessment, writing in the prestigious scientific journal, *Nature*, of March 24, 1983, Francis Giles raises the question:

What is wrong with Muslim science? This is what he says: "At its peak about one thousand years ago, the Muslim world made a remarkable contribution to science, notably mathematics and medicine. Baghdad in its heyday and southern Spain built universities to which thousands flocked: rulers surrounded themselves with scientists and artists. A spirit of freedom allowed Jews, Christians and Muslims to work side by side. Today all this is but a memory.

Expenditure on science and technology may have increased in recent years though that increase has been, perforce, limited to oil-rich countries. Some of these countries are busy fighting wars which cost billions of dollars – no doubt they have little time for science. Trade structures are dominated by imported technology and most countries have economic and scientific systems geared to imitation rather than originality.

Even the recent wealth provided by oil exports makes relatively little difference. science policy and politics, much to the displeasure of many scientists, are closely linked in the Middle East. The region is dominated by dictatorships, benevolent or otherwise, further complicating any attempt to allow science to take root indigenously. Not surprisingly, the brain drain to industrialized countries continues to debilitate intellectual life throughout the Middle East.

The same issue of *Nature* contains another article on "Research Manpower in Israel" from which I quote: "The need for a substantial increase in the number of academically trained people to work in research and development is widely accepted. The National Council for Research and Development has urged that

their country will need 86,700 such people in 1995, compared with 34,800 in 1974 – an increase of 150 percent.” Compare the figure of 34,800 with 45,136 researchers in all Islamic countries (the population ratio is around 200). The article continues: “In the 1960s, Professor Derek de Solla Price of Yale University developed a method for measuring scientific manpower in various countries based on the total number of researchers who had papers published in major professional journals and concluded that in this country, there are five times as many scientists as would be expected for its population and gross national product. Price insists that the situation is no different today; the country still possesses an enormous reservoir of trained people, something for which she has every reason to be grateful because her scientists and technicians more than compensate for the lack of oil and minerals.”

The New Gulf University

With this bleak picture of science in the Arab-Islamic Commonwealth, is it any wonder that the prospect of a super-University in the Arab-Islamic lands excites me, first and foremost to remedy the situation in the pursuit of the traditional basic sciences of Physics, Chemistry, Mathematics and Biology and, at the highest levels, as a prelude to sciences in application. My vision is that of prestigious universities and science arising – perhaps one in each of the six regions of Islam – the new Gulf University among them, consisting of centers of excellence, second to none in quality in the world, in one or more of the scientific disciplines, experimental and theoretical. These centers would be open internationally, their facilities would be among the finest in the world, the modalities of their operation non-bureaucratic. And there would be guaranteed financial access to these centers and their facilities for all researchers within the Arab-Islamic Commonwealth, so that the poorest faculties in the poorest of the Arab-Islamic countries can also keep in touch with living science through using these facilities.

The men to staff such facilities would come internationally, but in particular from the seventh region of Arab-Islamic science. This region consists, in Zahlan's count, of the twenty thousand researchers from the Arab-Islamic countries who are now working in Europe and America. I have the vision of these men coming to Bahrain and other super-Universities, at the least as part-time associates, to bring about the renaissance of sciences in our Commonwealth through their active contact. This will happen provided we create here the conditions which prevailed in the days of early Islamic science, particularly in this region.

The Reasons for Muslim Pre-Eminence in Sciences before 1000 AD and for the Subsequent Decline

What were the conditions which helped the Muslims develop sciences at a feverish rate in the eighth, ninth, tenth and eleventh centuries? What were the reasons for their pre-eminence? One may think of three: first and foremost, the

Muslims were following the repeated injunctions of the Holy Qur'an and the Holy Prophet. According to Dr. Muhammad Aijazul Khatib of Damascus University, nothing can emphasize the importance of science more than the remark that "in contrast to 250 verses which are legislative, some 750 verses of the Holy Qur'an – almost one-eighth of it – exhort believers to study Nature – to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the Community's life."

The second reason, which is connected with the first, was the status accorded in Islam to men of knowledge and science – the 'alims. The Holy Qur'an emphasizes the superiority of the 'alim, the man possessed of knowledge and science, by asking: how can those who do not possess these attributes ever be equal to those who do?

The Prophet of Islam said: "The quest for knowledge and science is obligatory upon every Muslim, man and woman." He enjoined his followers to seek 'ilm even if they had to travel to far Cathay in its search. Clearly in the context of China, he was emphasizing science and not religious knowledge, besides pointing out the internationalism of the scientific quest.

This brings us to the third reason for the success of the scientific enterprise in Islam: its international character. The Islamic Commonwealth itself cut across nations and color; moreover, early Muslim society was very tolerant of men from outside it, and of their ideas.

An aspect of this reverence for the sciences in Islam was the patronage they enjoyed in the Islamic-Arabic Commonwealth. To paraphrase what H.A.R. Gibb has written about Arabic literature to the parallel situation for the sciences: "To a greater extent than elsewhere, the following of the sciences in Islam was conditional on the liberality and patronage of those in high positions. Where Muslim society was in decay, science lost vitality and force. But so long as, in one capital or another, princes and ministers found pleasure, profit or reputation in patronizing the sciences, the torch was kept burning."

This situation did not last indefinitely however, and after 1100 AD science in Muslim lands started to decline. By 1350, the decline was almost complete.

Why did we in Islamic lands lose out?

No one knows for certain. There were indeed external causes, like the devastation caused by the Mongols, but grievous though it was, it was perhaps more in the nature of an interruption. Sixty years after Genghis, his grandson Halaku was founding an observatory at Maragha, where Nasir-ud-din Tusi worked. In my view, the demise of living science within the Islamic commonwealth was due more to internal causes of discouragement to innovation, *taqlid* and of isolation of our scientific enterprise.

To emphasize this, consider Imam Al-Ghazzali's (1058-1111 AD) injunctions in the first chapter of his great *Ihya-e-'Ulum-ud-Din* (The Revival of Religious Sciences). Imam Ghazzali laid stress upon the acquiring and creating of those sciences, which are necessary for the development of Islamic society.

specifically mentioning Mathematics and Medical Sciences. He designated these sciences as *Fard Kefayah* – an obligation for the whole community, but one, which can be discharged on its behalf by a certain number of its members, otherwise the entire community would consist of transgressors. In his *Al-Munqidh min al-Dalal*, the Imam says, “A grievous crime indeed against religion has been committed by a man who imagines that Islam is defended by the denial of the Mathematical Sciences, seeing that there is nothing in the revealed truth opposed to these sciences by way of either negation or affirmation, and nothing in these sciences opposed to truth of religion.” These injunctions notwithstanding, soon after Imam Ghazzali wrote, the temper of the age had turned away from science, either to Sufism with its other-worldliness or to a lack of tolerance and *taqlid* in Sciences as in other fields of learning. [...] This intellectual isolation continued – even during the great empires of Islam, the empires of Osmani Turks, of the Iranian Safvis, and of the Indian Mughals. It is not that the Sultans and the Shahinshahs were not cognizant of the technological advances being made by the Europeans; they could hardly have been unaware of the intrusive superiority of the Venetians or the Genoese in the art of gun-founding, or of the navigational and ship-building skills of the Portuguese who controlled the oceans of the world, including all oceans bordering on Islamic lands, and even the Hajj sea routes. But they never seem to have realized that navigational skills of the Portuguese were not accidental; these had been scientifically developed and sedulously cultivated starting with the research establishment of Sagres set up in 1419 by Prince Henry the Navigator.

But even when they envied and sought the technologies involved, they failed to understand the basic interrelation between sciences and technology. In 1799, for example, Selim III introduced the modern studies of algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey – and imported French and Swedish teachers – so as to rival the European skills of gun-founding. But he failed to accent basic scientific research in these subjects, and Turkey never caught up with Europe.

Thirty years later, Muhammad Ali in Egypt had his men trained in the arts of surveying and prospecting for coal and gold. But it did not strike him, or his successors, to train Egyptians long-term in the basic sciences of geology. Even today, when we have come to recognize that technology is the “sustenance” and the “power”, we have not appreciated that there are no short cuts in it, that basic science and its creation must equally become part of our civilization as a precondition of a mastery of science in application and technology. If one was being Machiavellian, one might discern sinister motives among those who try to sell us the idea encapsulated in the catchphrase “technology transfer” without “science transfer”.

Science Transfer and Technology Transfer

Let me elaborate on this theme, for this is central to what I want to say. I shall illustrate through some historical, as well as recent, examples of how scientific research impinges on modern technology.

My first example is Faraday's unification of electricity and magnetism, accomplished in the last century. Before Faraday, one thought of the electric and the magnetic forces as two distinct forces with no interrelation between them. Electricity was typified by the phenomenon of thunderstorms; magnets were bar-magnets, deflected by the earth's magnetism. Faraday, experimenting in his basic sciences' laboratory at the Royal Institution in London's Piccadilly, discovered an amazing interrelation between these two disparate forces. Move an electrically charged object in the vicinity of a magnet, and the magnet suffers deflection.

The conclusion of this and similar experiments was inescapable and sensational. The magnetic force is not an independent force; electrically charged objects produce electric forces when they are stationary; they give rise to magnetic forces when moved. Electricity and magnetism had been united and unified – this was one of the greatest discoveries in Physics of all time. And when Faraday was making his experiments, no one could have imagined that this simple Physics discovery in a laboratory in a fashionable and dilettante part of London would lead to the entire corpus of the electrical power generation.

Just to emphasize how relatively useless Faraday's work was thought to be by his contemporaries, consider the assessment of one of them, Charles Burney, of the uses of electricity versus music. "Electricity is universally allowed to be a very entertaining and surprising phenomenon, but it has frequently been lamented that it has never yet, with much certainty, been applied to any very useful purpose ... (while) it is easy to point out the humane and important purpose to which music has been applied. Many an orphan is cherished by its influence, and the pangs of child-birth are softened and rendered less dangerous."

The story of unification of electricity with magnetism continues with Maxwell who immediately followed Faraday. Maxwell asked himself the question: Faraday has shown that moving electric charges produce magnetic forces, what would happen if electric charges were accelerated rather than moved with uniform velocity? Maxwell pondered theoretically on this question; he found Faraday's equations inconsistent – they had to be modified if electric charges were accelerating. By one of the greatest acts of intuition in intellectual history, he supplied the correct modification and discovered, to his amazement, that an accelerating electrically charged object must emit electromagnetic radiation. He could compute the velocity of this radiation – again to his surprise, this velocity turned out to be identical to the velocity of light, then known with fair precision from experiment. Could light be electromagnetic radiation, produced by accelerating electrical charges embedded inside incandescent matter? Could we accelerate electrically charged particles in the laboratory and produce light? Could we verify Maxwell's theory directly in the laboratory?

A few years after Maxwell's death in 1879, Hertz in Germany carried out such experiments with accelerating electric charges. Every one of Maxwell's predictions was found correct; the spectrum of Maxwell's predicted radiation consisted not only of light waves, but also of waves of longer wave length (radio waves) as well as waves of shorter wave length (X-rays). Thus, from a single theoretical calculation done by an obscure professor at the Cavendish Laboratory – a laboratory endowed not by the State, but by a private individual, Lord Cavendish and his family – flowed the marvels of radio, television and the modern communication systems, as well as the medical facility to see through a human body with X-rays. These discoveries we in Arab-Islamic lands employ in our service along with the rest of mankind, hardly acknowledging the debt humanity owes to that modest physicist, Maxwell, and his solitary calculations. Maxwell's hundredth anniversary fell due in 1979, some six men congregated from the University of Glasgow at his grave and that was all the homage the world paid him.

My next example is that of fission. This is the breaking apart of a heavy overweight nucleus, like uranium, into two or more fragments when impacted by a slow-moving projectile like a thermal neutron. No one was looking for it – no one suspected it. The great Italian physicist Fermi, working in the dingy laboratories of the Department of Physics at the University of Rome, could have found these fission fragments in the debris deposited in his test tube, for they were there, but he was not looking for such fragments and missed them. The phenomenon was rediscovered in Germany at the Kaiser Wilhelm Institute for basic sciences in December 1938 – not by physicists but by two nuclear chemists, Hahn and Strassman. In their paper, the authors said, "As nuclear chemists who are close to physicists, we are reluctant to take this step that contradicts all previous experiences of nuclear physics." With this humble announcement began the age of nuclear energy for peace and for war. The equipment, the apparatus used, was so simple, even a humble laboratory in a poor Arab-Muslim country could have afforded it. Today, in the context of nuclear energy, European, American, Russian, Japanese and Chinese laboratories are experimenting with the phenomenon of fusion – the taming of the energy release in a hydrogen-explosion. These are at present laboratory experiments; as yet not commercial technology. The European nations have together created a joint laboratory – JET – at Culham in the UK. The UN Agency, IAEA, is projecting a joint device for the world; to my knowledge, no Arab-Islamic nation has yet asked to join this project. With Russian help, Libya has had the foresight to set up a small Tokamak device in Tripoli for experimentation in this field, but has not yet created the modalities through which teams of experimenters from Arab-Islamic or African countries could come and use this device. The Centre at Trieste regularly provides theoretical workshops for this, led by men from the prestigious laboratories of the world; at present, this provides one of the few entrees for Arab-Islamic physicists to this field.

My next example is in the area of biotechnology. As is well-known, the modern advances in genetics started with the unraveling of the genetic code by Watson and Crick. In the synthesis it has provided in giving the basis for all known life, this has been one of the most synthesizing discoveries of the 20th century, possibly of all time.

The great discovery in biology was made at Cambridge in April 1953 by two contemporaries of mine, one American, the other British – working at the Cavendish Laboratory for basic physics. One of my American pupils for Ph.D. in theoretical physics, Walter Gilbert, with whom I work on dispersion phenomena, was a neighbor of the genetic code's American co-discoverer, J.D. Watson, in Cambridge. When Gilbert left me in 1956 after his Ph.D., both he and Watson went back to Harvard. The next time I saw my pupil, Gilbert, was in 1961 in the United States. Assuming that he was still working on some problem in theoretical physics, I asked him what he was up to. He was somewhat sheepish. He said, "I am sorry, you will be ashamed of me; I am spending my time growing bacteria." Watson had seduced him for genetics. Gilbert soon discovered a most elegant technique for deciphering the genetic code. For his work, he received a Nobel prize in Chemistry in 1980. In 1981, he left his chair at Harvard to found a company which exploits, among others, techniques of genetic manipulation to manufacture human insulin. This company is called Biogen and is registered in Switzerland. It went public recently. Apparently, Gilbert's first investment in the company (of which he is President) was of US \$4,000; it is currently worth more than fourteen million dollars.

Notice the mutuality of science and technology. Notice that the greatest discovery in molecular biology is made in a laboratory for physics, by men trained in the use of X-rays with fairly modest equipment. Notice Gilbert's transition from research in theoretical physics to fundamental genetics and then to practical genetic engineering. The point I am trying to make is twofold: first, science and technology go hand-in-hand in modern times; second, there is a premium placed on excellence and brain power in our rival civilizations. We must ask ourselves: do we provide like opportunities for our best young men, nurturing their talents for our civilization, or do we leave them to wither away, or if they are strongly committed to science, to migrate and enrich the countries of Europe and America with their talents and their contributions?

Perhaps my examples appear too distant for comfort, though the biotechnological example is not all that far-fetched. Perhaps the intervening centuries of neglect of sciences have lulled us into feeling that we can never catch up in the creation of sciences, and that we need not even try. I started in my first example with Faraday's and Maxwell's unification of two of the fundamental forces of nature – of electricity with magnetism – in the last century. I said that from this unification flowed the age of electric power and next, the age

of wireless communication. When a hundred years after Maxwell, in the 1960s, my colleagues at Harvard, Glashow and Weinberg, and myself independently took the next step of postulating a unification of two further forces of nature – of electromagnetism with the weak nuclear force of radioactivity – even the *London Economist* took note and counseled perceptive businessmen not to ignore the likely economic consequences of this new unification.

Our theory had been indirectly confirmed through its consequences for diverse phenomena in nuclear and atomic physics by 1978. This year, in January, the great joint European experimental laboratory at Geneva provided the direct confirmation of our theory. We have predicted the existence of three mediators of the weak nuclear force W^+ , W^- and Z^0 s. We had specified their expected masses as a consequence of the unification. The January experiment showed that W^+ and W^- indeed do exist, with precisely the predicted masses. This week the last particle, the Z^0 , has also been identified among the products of the collisions of protons and anti-protons in the 6 km accelerator at CERN. To obtain a beam of anti-protons, the laboratory had to invent a new principle of "stochastic cooling" of anti-protons and to execute this idea with a technical brilliance of the highest order at a cost of around fifty million dollars. This same laboratory is now engaged in building a new accelerator of twenty-seven kms circumference under the Jura mountains of Geneva for further experimentations with our theory. This will cost them half a billion dollars and will be completed by 1987. So far, the only comment on these discoveries made by an Arab-Islamic journal was last month; this journal, published in London, accused me of the following in my research on the unification of these fundamental forces, "the heretical Sufi Doctrine of Wahdat-ul-Wujud!"

This journal has sagely counseled that we in Islam should not concern ourselves with advances in science. We should concentrate on imitative technology, assuming someone will sell it to us. That is what the Japanese are supposed to have done. We forget that the Japanese already have won four Nobel Prizes in science – three in physics and one in chemistry. Their base in fundamental sciences is as strong, or in some cases, stronger than in the West. We forget that it was this unspoken and unsung base on which they have built their innovative successes in technology. We forget that an accelerator like the one at CERN develops sophisticated modern technology at its furthest limit. I am not advocating that we should build a CERN for Islamic countries. However, I cannot but feel envious that a relatively poor country like Greece has joined CERN, paying a subscription according to the standard GNP formula. I cannot rejoice that Turkey, or the Gulf countries, or Iran, or Pakistan seem to show no ambition to join this fount of science and get their men catapulted into the forefront of the latest technological expertise. Working with CERN accelerators brings at the least this reward to a nation, as Greece has had the perception to realize.

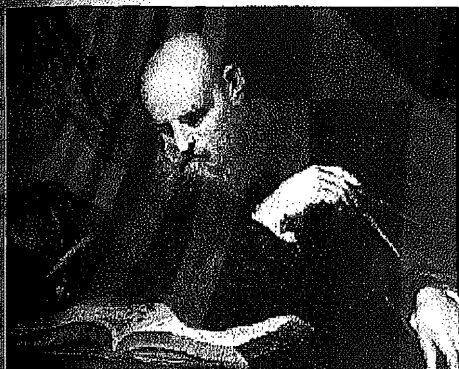
Let me close this part of my discussion about the mutual interrelation of science and technology with an example, nearer home, from the field of solar energy. This is a field where research is being carried out by the universities in the Gulf as well as in the North African and Middle Asian universities of the Islamic countries. The basic problems, for example, with the development of cheaper photovoltaic devices, are material sciences problems. Solar energy is collected, and converted by materials that are optically or photoelectrically suitable. An optical converter must use as little material as possible; how little is determined by the penetration depth of the solar light and the drift-length of the "excited state" on which the conversion is based. One can easily determine that the parameters entering these basic processes lead to thicknesses of material of the order of one micrometer. This then is the domain of thin films. Such films are cheap to make, but there is no way of making them with the perfection of a single crystal. Thin films are polycrystalline or amorphous. And they carry a large density of defects. Up to now, it is these defects which have limited the thin film devices to low conversion efficiencies. Thus, before any technological amelioration can come, one must solve the problems of basic solid state physics, of classifying the major defect phenomena, their effect on electron dynamics and problems of catalysis of the growth mechanism that makes these defects harmless.

What I am saying is that efficient photovoltaics do not depend on the engineers' tinkering with solid state materials; the problem is one of solid state physics. And it is this problem of basic science which the Japanese solid state physicists have set themselves to solve systematically, before their counterparts in the USA or Europe. The Japanese will win this prize, not only because they are the more meticulous technologists, but also because they are the systematic physicists, with scientific facilities which, in many cases, are superior to what their rivals possess. The point I am making is that what the University of the Gulf will need, if it wishes in the long run to develop first rate research on photovoltaics, is a basic surface physics laboratory, in addition to technological support. The same sentiment was endorsed by the London *Economist* which, in its issue of September 27, 1980, has this to say on the cherished mastery of solar energy: "If solar energy is to provide the solution to the world's fuel crisis, that solution will not emerge from low-technology rooftop radiators (which) rely on nineteenth century (science). A breakthrough (will) come from applying quantum physics, biochemistry or other sciences of the twentieth century. Today's technology-based industries all depend on new science."

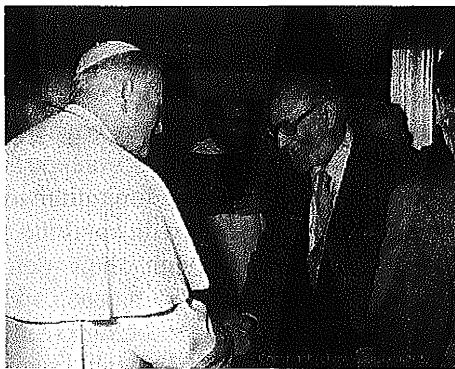
I hope I have convinced you that in the conditions of today there can be no high technology without first-rate science. I suspect some of us believe that technology is neutral, while science is value-loaded; modern science can lead to rationalism, or even apostasy – that scientifically trained men among us will "deny the metaphysical presuppositions of our culture". To such thinking, all I can say is: Do not fight the battles of yesterday when in the ninth and the tenth

centuries the so-called "rational natural philosophers", with their irrational and dogmatic faith in the cosmological concepts they had inherited from Aristotle, found difficulties in reconciling their concepts with their faith.

These battles were even more fiercely waged among the Christian schoolmen of the Middle Ages. This was inevitable as Maurice Bucaille has shown in his perceptive work *The Bible, The Koran and Science*, the problems which concerned the schoolmen were mainly problems of cosmology and metaphysics: Is the world located in an immobile place; does anything lie beyond it; is there more than one world; are the planets and stars carried around in physical spheres? Does God move the primum mobile directly and actively as an efficient cause, or only as a final or ultimate cause? Are all the heavens moved by one mover or several? Are the spheres moved by intelligences, or by some principle inherent in matter? Do celestial movers experience exhaustion or fatigue? Are all the spheres of the same nature? Are they concentric with the earth as common center, or is it necessary to assume eccentric and epicyclic orbs? What was the nature of celestial matter? Was it like terrestrial matter in possessing an inherent substantial form and inherent qualities such as being hot, cold, moist, and dry? The answers sought were either from an interpretation of the scriptures or from



50. Galileo Galilei



51. Pope John Paul II and Abdus Salam

the authority of Aristotle." No wonder when Galileo tried, first to classify those among the problems which belonged to the domain of Physics and then to find answers just to this class through physical experimentation, he was persecuted. Restitution for this is being made now three hundred years later.

I attended a special ceremony the day before yesterday in the Vatican where His Holiness the Pope, in the presence of thirty-three Nobel Laureates and three hundred other scientists, declared: "The Church's experience, during the Galileo affair and after it, has led to a more mature attitude. ... The Church herself learns by experience and reflection and she now understands better the meaning that must be given to freedom of research ... one of the most noble attributes of man.

It is through research that man attains Truth. ... This is why the Church is convinced that there can be no real contradiction between science and faith.

(However) it is only through humble and assiduous study that (the Church) learns to dissociate the essential of the faith from the scientific systems of a given age, especially when a culturally influenced reading of the Bible seemed to be linked to an obligatory cosmogony."

In his remarks, the Pope stressed the maturity which the Church had reached in dealing with science; he could also have emphasized the converse phenomenon, the recognition by the scientists from Galileo's time onwards of the limitations of their disciplines – the recognition that there are questions which are beyond the ken of science. We may speculate about them, but there may be no way to verify empirically our speculations. And this empirical verification is the essence of science. We are humbler today than, for example, Ibn Rushd was. Ibn Rushd was a physician of great originality with major contributions in the study of fevers and of the retina; this is his claim to immortality in Science. However, in a different discipline – cosmology – he accepted the speculations of Aristotle, without recognizing that these were speculations which future experiments may falsify. The scientist of today knows when and where he is speculating; he would claim no finality for the associated modes of thought. And even about accepted facts, we recognize that newer facts may be discovered which, without falsifying the earlier discoveries, may lead to generalizations; in turn, necessitating revolutionary changes in our concepts and our "worldview". In Physics, this happened in the beginning of this century with the discovery of relativity and quantum theory. It could happen again; when our present constructs could appear as limiting cases of newer concepts, still more comprehensive, still more embracing.

But even to know the limitations of our sciences, one must be part of living science; otherwise one will continue fighting yesterday's philosophical battles today. Our men, through their demonstrated ability, must belong to that aristocracy of creators of science, where one is respected and all doors are opened if one deserves to belong to it. Like all aspects of human activity, what the Arab-Islamic Commonwealth needs are men – an elite class of them – who have shared in the pride of having created some parts of science. Our youth are craving to meet this challenge; it is this challenge, which makes them migrate to Western universities and institutions. Trust them; they do possess the highest potential. If the new University of the Gulf will provide them with opportunities to create science – and this, by definition, is the function of a university – they will never leave. And after providing them with these facilities, do not hustle them. It takes a decade or more of stability to build traditions of living science.

Steps Needed to Excel in Sciences

So then, how can we turn the pages of history back, and excel in science and technology once again? How can the new Gulf University ensure this excellence and attract these men back again?

In keeping with the obligations laid on us by the Holy Qur'an and the Holy Prophet, our society as a whole, and our youth in particular, must develop a

passionate commitment towards bringing about a renaissance of the sciences. We must impart hard scientific training to more than half of our manpower; we must pursue basic and applied sciences, with 1-2% of our GNP spent on research and development, with at least a quarter of one-third of this on pure sciences.

This was done in the USSR. This was done in Japan, after the 19th century Meiji revolution. And this is what is being undertaken today – in a planned manner, at a frantic speed – by the People's Republic of China, with defined targets in space sciences, genetics, microelectronics, high energy physics, agriculture, and in the control of thermonuclear energy. There is a clear recognition in these societies that basic science is relevant science that the frontier of today is tomorrow's application, and that one must remain at the frontier. They have realized that there is only one path to gaining ascendancy in science and technology – master science as a whole.

These societies are not seduced by slogans of "Japanese" or "Chinese" or "Indian" science. They do not feel that the acquiring of science and technology will destroy their cultural traditions: they do not insult their own traditions by believing that these are so fragile. In this context, one may recall that the GNP of the Islamic-Arabic nations exceeds that of China, while their human resources are not significantly smaller. And China has a lead of no more than a decade or so in the sciences over the lands of Islam.

Earlier, I spoke of patronage for the sciences. One vital aspect of this is the sense of security and continuity that a scientist-scholar must be accorded for his work. Like all humans, a scientist or technologist can only give of his best if he knows he will have security, respect and equality of opportunity for his work, and is shielded from all forms of discrimination, sectarian and political.

I have referred throughout to a Commonwealth of Science for the Islamic and the Arab countries, even if there may be no political commonwealth of these countries yet in sight. Such a Commonwealth of Science was a reality in the great days of Islamic science, when central Asians like Ibn Sina and Al-Biruni would naturally write in Arabic. In those days, their contemporary (and my brother in physics), Ibn Al-Haitham, could migrate from his native Basra in the dominions of the Abbasi caliph to the court of his rival, the Fatimi caliph, and be sure of receiving respect and homage – despite the political and sectarian differences that were no less acute then than they are today.

This Commonwealth of Science needs conscious articulation and recognition once again, spiritually and physically, by both us, the scientists, and by our governments.

Today, we, the scientists from the Islamic countries, constitute a very small community – one-hundredth to one-tenth in size, in scientific resources, and in scientific creativity, compared to the international norms. We need to band together, to pool our resources, to feel and work as a community. We need the articulation of a compact conferring of immunity for, say, the next twenty-five

years, during which those within this commonwealth of sciences, this *Ummat-ul-'ilm*, would not be discriminated against on sectarian or national grounds.

To summarize, the renaissance of the sciences within an Islamic and Arab commonwealth is contingent upon five cardinal preconditions: passionate commitment, generous patronage, provision of security, absence of discrimination, self-governance and internationalization of our scientific enterprise.

What steps can the new Gulf University take to nucleate and sustain such an *Ummat-ul-'ilm*?

Assuming that this will be a post-graduate University, it will strive, first and foremost, to create centers of research of international standards in basic sciences. These could emphasize Mathematics, experimental Solid State Physics of microelectronics and communications system, and Biotechnology, besides the regional disciplines of marine and desert sciences. The University will actively strive to link to it, through these centers, the best brains internationally, and in particular those from the Arab-Islamic Commonwealth. To facilitate these latter linkages, there will be Federation Agreements with institutes and groups of researchers in the six regions of the Arab-Islamic Commonwealth. The funds for the stay and the travel of teams of such researchers will be provided by the Gulf University. This is the pattern we follow in Trieste (Table 1) where we have Federation links with eighty-three institutes in developing countries – forty-seven of these in the Arab-Islamic world – where we assign to researchers at each institute 40-120 days of visits at our expense. We have, in addition, for eminent individual researchers, a scheme of personal Associateships based on merit; at any one time, we have two hundred Associates, each appointed for a six year term. During these six years, an Associate may come to the Centre thrice at times of his choosing, with a minimum stay of six and a maximum stay of twelve weeks. We pay the Associate's fare and his expenses in Trieste, but no salary. There are no formalities. The Associate simply writes to say he is arriving. Such a scheme would be particularly valuable for men from the Arab-Islamic Commonwealth now working in the seventh region I mentioned – Europe and USA. These are the men whose presence at the campus of the Bahrain University will enrich it intellectually; they will bring to it the newer ideas, newer techniques, newer thrusts, with a minimum of delay. If the Gulf University can become a second home for these men with a minimum of formality, it will have achieved a great deal.

I have mentioned an international laboratory in materials sciences for Bahrain, with specialization in microelectronics and modern electronic communications, including space satellite communication, to help also with the banking communications needed at Bahrain. Such a laboratory was in fact proposed for the University of Jeddah. The idea was to emphasize science transfer in addition to technology transfer and to create international laboratories

in the fields of materials sciences, including surface physics and a laboratory with a synchrotron radiation light source. The facilities created would have been in the highest possible international order; the laboratories would have been opened to teams of international researchers, who would congregate and work at Baghdad, just as they congregate now at the great laboratories in Hamburg, Geneva or Paris. The project apparently has not matured, mainly I believe, because it had sponsorship of a single rather than a consortium of universities. I would hope that the project can be revived for a new super Gulf University, thereby making it accessible to researchers internationally, and particularly to all the Gulf, as well as all the other universities in the Arab and Islamic countries.

I have also mentioned a super laboratory at Bahrain for biotechnology. In this context let me mention that the UNIDO organization at Vienna is sponsoring an International Centre for this subject, like the Centre at Trieste. A competition is being organized for its location; six locations have offered facilities – these are Pakistan, India, Cuba, Thailand, Belgium and Italy. No Arab country has offered a location. If Lahore, in Pakistan, wins the competition, the UNIDO International Centre at Lahore would naturally have close links with the Gulf University facility at Bahrain.

Finally, I have emphasized an International Centre for Mathematics, with ramifications in computing sciences. As we all know the modern tradition in mathematics originated at the institutes in the Gulf Region, particularly in Baghdad in the eighth, ninth, tenth and eleventh centuries, with the creation of algebra, trigonometry and analytical geometry. I do not see why we cannot create the same conditions of excellence today in mathematics and make Bahrain a world crossroads for this subject. As you probably know, one of the leading mathematicians in the world – currently a Professor at Oxford – who was awarded the most prestigious honor anyone can aspire to in mathematics (the Fields Medal) is of Arab descent. I do not see why such men should not hold joint appointments between their European places of work and Bahrain and build up a modern school of Mathematics here.

Conclusions

Let me conclude. Why am I so passionately advocating our engaging in this enterprise of creating knowledge? This is not just because Allah has endowed us with the urge to know, this is not just because in the conditions of today, knowledge is power and science in application the major instrument of material progress, it is also because as part of the international world community, one feels that lash of contempt for us – unspoken, but still there – of those who create knowledge.

I can still recall a Nobel Prize Winner in Physics some years ago, from a European country, saying this to me: "Salam, do you really think we have an obligation to succour, aid and keep alive those nations who have never created or added one iota to man's stock of knowledge?" And even if he had not said this, my self-respect suffers a terrible hurt whenever I enter a hospital and find that

Table 1. The number of visitors from Arab-Islamic countries to the International Centre for Theoretical Physics, Trieste Member States

		No. of visitors from 1970-82	Federation agreements	GNPUS billions (UN 1980)
GROUP I	Bahrain	2	-	2.1
	Iraq	81	1	30.0
	Kuwait	46	2	22.0
	Oman	-	-	2.6
	Qatar	6	1	3.8
	Saudi Arabia	44	-	62.6
	United Arab Emirates	1	-	15.0
	Yemen Arab Republic	23	1	2.4
	Yemen's People's Republic	1	1	0.9
GROUP II	Jordan	62	2	3.0
	Lebanon	79	2	n.a.
	Syria	38	3	8.9
	Palestine (West Bank)	5	1	n.a.
GROUP III	Afghanistan	10	-	2.6
	Iran	99	3	n.a.
	Maldives	-	-	0.03
	Pakistan	293	2	20.9
	Turkey	238	7	58.8
GROUP IV	Bangladesh	134	1	8.3
	Indonesia	92	-	52.2
	Malaysia	58	-	17.9
GROUP V	Algeria	69	1	28.9
	Djibuti	-	-	0.14
	Egypt	461	11	18.6
	Libya	43	-	23.3
	Morocco	33	1	14.4
	Sudan	83	2	6.6
	Tunisia	25	-	6.9
GROUP VI	Central Africa	2	-	0.5
	Cameroon	20	-	4.6
	Chad	-	-	0.5
	Comoros	-	-	0.1
	Ethiopia	5	-	3.9
	Gabon	4	-	2.1
	Gambia	-	-	0.15
	Guinea-Bissau	-	-	0.2
	Guinea	4	-	1.5
	Ivory Coast	7	-	8.5
	Mali	24	-	0.9
	Mauritania	3	1	1.6
	Niger	7	-	1.4
	Nigeria	157	4	55.3
	Senegal	33	-	2.4
	Sierra Leone	34	-	0.8
	Somalia	4	-	n.a.
	Togo	16	-	0.8
	Upper Volta	18	-	1.0
Grand Total		2,364	47	

almost every potent life-saving medicament of today, from penicillin to interferon, has been created without our share of input from any of us in the Third World, or from the Arab-Islamic lands. The 20th century has been a century of great synthesis in science – the syntheses represented by quantum theory, relativity and unification theories in physics, by the Big Bang idea in cosmology, by the genetic code in biology, by ideas of plate tectonics in geology; likewise in technology, the conquest of space and the harnessing of atomic power. Just as in the 16th century when the European man discovered new continents and occupied them, the frontiers of science are being conquered one after another. Do you not feel as passionately as I do that our men in Arab-Islamic lands should also be in the vanguard of making these conquests?

I wish to conclude with two appeals – one to those responsible for creating the new University, and particularly, to the scientists among them; and the second to our rulers. First the science administrators: There are few scientists in our area on whom you can build. This however would not be so if we can band together in an Ummat-ul-'Ilm and create a genuine community for all Arab-Islamic lands. Believe me, our situation is not that desperate, particularly if conditions are created to associate those from our lands working in the seventh region of Europe and USA with our enterprise. I can only say, for all our present weaknesses, let us not be the less ambitious. Let our plans for our institution building be audacious. With ambition, and with involvement, will come competence, for this is Allah's promise to all those who strive.

And finally, I wish to appeal to those responsible for our affairs and for funding this University and other projects I have spoken about. Science is important because of the underlying understanding it provides of the world around us and of Allah's designs; it is important because of the material benefits its discoveries can give us and finally because of its universality. It is a vehicle of cooperation of all mankind and in particular for the Arab and Islamic nations. We owe a debt to international science, which in all self-respect, we must discharge. However, the scientific enterprise cannot flourish without your generous patronage as in the past centuries of Islam. I am now living and working in a small city of one-quarter of one million inhabitants. In this city there is a Bank – Casa di Risparmio – which donated 1.5 million dollars for the building in which the International Centre which I created is housed. This city has now pledged from its regional resources forty million dollars for the proposed UNIDO Centre for Biotechnology. I feel amazed at their perceptiveness, their love of science and eventually of technology. Shall our cities and banks not rival this example? The international norms of 1-2% of GNP I have been speaking about would mean expenditures of no more than two to four billion dollars annually for the Arab and the same amount for the rest of the Islamic world on research and development, one-quarter to one-third of this spent on pure sciences. In 1973, the Pakistan Government, on my suggestion, requested the Islamic Summit in Lahore

Table 2. R&D Manpower in Islamic countries

Name of country	Year	Population (millions)	R&D scientists engineers
Algeria	1972	16.8	242
Bahrain	1967	0.3	-
Bangladesh	1973	79.0	-
Cameroon	1976	7.5	-
Chad	1971	4.0	85
Comoros	-	-	-
Djibuti	1973	0.1	-
Gabon	1970	0.5	8
Gambia	1973	0.5	-
Guinea	-	-	-
Guinea Bissau	-	-	-
Indonesia	1976	140.0	7,645
Iran	1974	33.0	4,896
Iraq	1972	11.1	1,486
Jordan	1977	2.7	452
Kuwait	1975	1.0	606
Lebanon	1972	2.5	180
Libya	1980	2.4	50
Mali	-	-	-
Malaysia	1970	11.9	-
Maldives	-	-	-
Mauritania	-	-	-
Morocco	-	-	-
Niger	1976	4.6	93
Nigeria	1970	65.7	2,200
Oman	-	-	-
Pakistan	1979	70.2	5,144
Qatar	1974	0.2	-
Saudi Arabia	1974	7.2	-
Senegal	1972	4.5	522
Somalia	1965	2.0	-
Sierra Leone	-	-	-
Sudan	1971	15.7	3,266
Syria	1970	7.4	-
Tunisia	1974	5.6	-
Turkey	1975	40.3	11,606
U.A.E.	-	-	-
Uganda	-	-	-
Upper Volta	-	-	-
Yemen Arab Republic	1974	5.0	60
South Yemen	-	-	-
Egypt	1976	37.0	10,655
Afghanistan	1966	14.8	330
Total			45,136

These figures are taken from the Secretariat Report presented to the first meeting of the Islamic Conference on Science and Technology, May 1983.

to create at least one Foundation for Science for all lands of Islam equal in size to the Ford Foundation, with a capital of one billion dollars. Eight years later, in 1981, such a Foundation was at last created but with just fifty million promised and six million dollars paid up so far. I am sure a banking community like that at Manama alone could rival Ford's benefaction if we really are serious about science. And this region has rich traditions in this respect. Imam Ghazzali, you may recall, paid a rich tribute in the 11th century, to the land of Iraq, when he said: "There is no country in which it is easier for a scholar to make a provision for his children." This was at the time when he was planning to become a recluse and to cut himself off from the world. We need not one such but a number of Science Foundations as in the West, run by the scientists themselves; we need international higher centers of learning within and without our universities, providing generous and tolerant continuity, for our men and their ideas. Let no future Gibb record that in the fifteenth century of the Hijra, the scientists were there but there was a dearth of merchants and princes with their generous patronage to provide for the facilities needed for their work. ■

26

International Commons: Sharing of International Resources

In 1945, Europe was devastated. Soon after, the United States took a remarkable initiative with the launching of the Marshall Plan to finance European recovery. Some thirty-two billion dollars were generously provided, amounting in the beginning, to a contribution of around 2.79% of the Gross National Product of the USA. A magnificent act of magnanimity, it was not pure altruism, because the USA knew that by building up Europe, it was contributing to the future prosperity for the entire Western world, including enhanced prosperity of the United States itself, through trade and commerce. It is unfashionable nowadays to speak in these terms, but one may have called this act Keynesianism at its best, inspired by the earlier successes of the New Deal in the United States itself. One of the results of this all too rare act of economic wisdom was that during the next decades – the sixties and the seventies – after Western Europe was back on its feet, the prosperity of all countries – including the donor country of the USA – increased to levels unmatched in world history before.

The Marshall Plan led to similar ideas for the United States and European aid to be extended to the developing countries. Here, of course, the needs were greater. Perhaps the sheer magnitude of the development tasks meant that the donors felt shy of doing as much as they had done for Western Europe. The aid packages were more meager. And there was one other limitation. Those were also the days of the hottest phases of the “Cold War”. The aid packages extended to the developing countries were not purely economic aid. The Cold War had imposed a selectivity; the most generous economic help went hand in hand with military aid. The donors also wanted the allotted sums to be spent in helping Western interest including Western exports.

As I mentioned earlier, the small quanta of aid funds were inadequate for the needs. Instead of 2.79% of the GNP of the Marshall Funds, this time the funds (contributed by OECD countries) never went beyond .5%, falling to around .34% by the 1970s. Even though the Pearson Commission set up in 1969, made its recommendation of aid quantum being fixed at .7% of the GNP of donor countries – a recommendation later endorsed by the Brandt Commission – these figures have never been met except by a very few of the donors. Thus the United States share has fallen to less than .2% with a fall also in the shares of the UK.

France, Federal Republic of Germany, Japan and others. And, furthermore, the Eastern bloc have never joined the aid consortia; their aid (.14% of GDP) – much smaller – is disbursed bilaterally. The OPEC countries started in the early 1970s with 1.18% of their GDP, went up to nearly 3% in 1975 and then declined (with a total of 7.7 billions) to 1.4% of GDP in 1981.

I am not so much concerned in this note with the precise aid percentages. I am much more concerned with the way in which the conceptual basis of such transfer of resources is presented. It is my belief, and I am sure Members of this Academy share this belief with me, that unless an idea has a sound, generally accepted conceptual currency behind it, it does not win adherence.

Some of the considerations on which a theory of transfer of resources to the developing world may be based may run as follows.

1) *Economic self-interest.* As emphasized earlier, in the case of US help to Europe, Keynesianism theories, which inspired the New Deal, may have been at the back of the Marshall Plan. Involved in this is firstly the idea that in order that societies should be economically well-off, one needs a large base of economic activity. Secondly, the securing of this large base needs, in its turn, the prosperity of all sections of the society, leaving no pockets of poverty, within the society. Thus, prosperity for all, an interdependence and a perceived mutuality of interests of all sections of the society, is the key idea with the Marshall Plan extending the scope of the society covered, from USA alone, to embrace also the continent of Western Europe. The Plan based itself on the view that the prosperity of the US would increase if Europe became prosperous, and able to exchange goods and services with the US.

What we are speaking about today is the carrying of these ideas further to include the developing countries. In the words of Willy Brandt: "The mutuality of interests can be spelled out clearly in the areas of energy, commodities and trade, food and agriculture, monetary solutions, inflation control ... and ground and space communications. The depletion of renewable and non-renewable resources, throughout the planet, the ecological and environmental problems, the exploitation of the oceans, not to forget the unbridled arms race, which both drains resources and threatens mankind – all of these also create problems which affect peace and will grow more serious in the absence of a global vision. ... Whoever wants a bigger slice of an international economic cake cannot seriously want it to become smaller ... Most industrialized countries, even during the biggest boom in human history, have not tried hard enough to get near the minimum aid target to which most of them had solemnly agreed. That record is not only disappointing but also reminds us that, had the target been met, several developing countries would now be importing more goods and services, thus mitigating economic difficulties of the North."

2) To highlight the economic interdependence, particularly in the context of producing job opportunities in the developed countries, Brandt contended: "Perhaps one can illustrate part of the problem from the development of some of the present industrialized countries in the nineteenth and early twentieth centuries. A long and assiduous learning process was necessary until it was generally accepted that higher wages for workers increased purchasing power sufficiently to move the economy as a whole. Industrialized countries now need to be interested in the expansion of markets in the developing world. This will decisively affect job opportunities in the 1980s and 1990s and the prospect of employment."

This sentiment was echoed also by J. Tinbergen et al. in their paper on "A New World Employment Plan". According to them, "The second element of a new world employment policy consists of an increase in international income transfers to Third World countries in order to increase employment in these countries. The resulting increase in welfare and purchasing power in these countries will lead to higher imports from the industrialized countries. This then will be an important stimulus to higher employment in the industrialized countries too."

The same statement comes from Masaki Nakajima: "In the past, of course we had the Keynesian approach to demand development. That, unfortunately, was geared to the development of a single economy. Today, in order to solve a massive problem like worldwide unemployment, I think we have to expand the Keynesian approach so it can be applied on a global scale. One possibly effective area would be toward a solution of North-South problems."

3) One may look upon aid as a compensation for the decline in commodity prices. Year after year we have seen that the weakness – economic, as well as political – of the developing countries has meant that the commodity prices have not kept up with the increase in prices of industrial goods. As Michael Manley, the Ex-Prime Minister of Jamaica, once explained: "In the 1950s, ten tons of sugar brought a Jamaican farmer a Ford tractor. In the 1970s the same tractor costs twenty-five tons of sugar. Why? Is it that the Jamaican peasant is subsidizing by a factor of 100% the social security and welfare of Ford plant workers?" And not only have the commodity prices not kept up with industrial prices, they have also seen such ups and downs that for a developing country there is no possibility of any rational planning of its economic future. These "vagaries" of price cycles are attributed to the vagaries of stock exchanges. Speaking plainly, is this not a type of organized brigandage, which the rich societies have permitted their stock-market speculators to indulge in?

As is well known, this economic weakness of the developing countries has led them to the brink of bankruptcy. The facts in respect of the economic situation of the developing world are stark. The non-oil producing developing countries have suffered a deterioration in their export earnings of some one hundred billion dollars annually between 1980 and 1983. At least fifty billion dollars of this are attributable to lower commodity prices. The pleas of the

developing countries to have some consideration given to the commodity prices have consistently fallen on deaf ears. On the testimony of the Ex-Chancellor Helmut Schmidt of Germany who wrote in *The Economist* of February 26, 1983, that the German Federal Republic put forward a proposal for stabilizing developing countries' exports of raw materials for international discussion as early as 1978. Unfortunately, according to him, this proposal was not taken up at the agenda of any of the international conferences. It is time, he says, to raise the proposal again. In the meanwhile the developing countries may be forgiven if they consider aid as part compensation for this decline of commodity prices.

4) One may look upon aid as part of the compensation for the 19th century exploitation of the riches of the developing countries – a transfer of resources from the ex-Colonies, ex-Empires, which enriched particularly some of the European countries and gave them economic prosperity.

5) One may point to the disparity of distribution of World Resources and the instability it creates. There is, at present, a tremendous disparity (Table 1) between the rich and the poor in the ultimate criteria of prosperity – the reserves of arable land, of forest, coal and iron. It is important to realize that the full scale occupation of empty regions of the globe – Siberia, Canada, Australia – took place in the 19th century and that it is of relatively recent origin. Some among those who plough the exhausted soils of Asia and Africa may not for long be able to avert their hungry gaze from the virgin soils of some fortunate and empty corners of this globe. It is hard for them to comprehend that there can exist parts

Table 1. The Disparity in Natural Resources (per capita)

	Asia	North America	USSR	Europe	Oceania	World
Agricultural area (hectares)	.54	2.63	2.8	.55	30	1.4
Accessible forest area	.20	2.07	5.4	.33	1.6	.96
Coal reserves (tons)	6.3	2000	90	960	812	365
Oil reserves (tons)	.8	27.8	16.9	.4		12.5
Iron ore reserves (tons)	16.4	389.6	502	59.8	25	102

(Estimates made by the United Nations in 1950 and quoted in *World Population and Production*, by W. S. Waytinsky and E. S. Waytinsky.)

of the world where 15 and 20% of agricultural land has to be "banked" and the farmers paid not to cultivate it in order that world prices of grain can be kept up. It is hard for them to believe that open spaces still exist in Canada, Australia, Siberia, and elsewhere, and that material rewards must be paid to those willing to pioneer their colonization. There is one lesson from history we must not forget: a world as polarized as ours is unstable; it cannot endure this way forever.

It was perhaps in recognition of this disparity and the instability which it breeds that Lyndon Johnson expressed himself thus: "Many of our most urgent problems do not spring from the Cold War or even from the ambitions of adversaries. They are the ominous obstacles to man's effort to build a great world society – a place where every man can find a life free from hunger and disease. Those who live in the emerging community of nations will ignore the problems of their neighbors at the risk of their own prosperity. ... There is no simple solution to these problems. In the past there would have been no solution at all. Today, the constantly unfolding conquests of science give man the power over his world and nature which brings the prospect of success within the purview of hope." Lyndon Johnson had the courage, pursuing this line of thinking, to allocate the funds which he saved from the defense budget of the United States to his programs against poverty in that country. One wishes there were more men like him who could declare that a similar consequence would follow global disarmament and cuts in military expenditure will mean more funds for global development.

These were some of the arguments for the transfer of resources. But what is needed is some sort of automaticity in these transfers and I wish to speak about this now.

In 1969, the Nobel Laureate, Linus Pauling, speaking at the Nobel Symposium held in Stockholm, on the "Place of Value in a World of Facts", made a plea for international taxation whereby the world distribution of wealth among the nations of the world may be adjusted by levying a tax on the nations with a higher GNP and providing the funds to those in the developing countries. Pauling spoke of the transfer of resources of the order of 200 billion dollars per year, about 8% of the world's then total income, which he thought was the right figure for an international income tax. I remember listening to Pauling and thinking to myself; this is a totally Utopian proposal. None took it very seriously at the meeting. Pauling thought it was possible to formulate a fundamental principle of morality, independent of revelation, superstition, dogma and creed and acceptable by all human beings in a scientific, rational way by analyzing the facts presented to us by the evidence of our senses. He said a major fact of our lives was that there is so much suffering in the world, much of it unnecessary and avoidable. To minimize this suffering we must provide every person not only with adequate food and shelter but also with education.

To produce the funds required, Pauling identified militarism as one of the major causes of human suffering. Militarism then cost the world over 250 billion dollars per year. It costs three times that much today. This amount of wealth wasted on military conflicts each year is greater than the total annual personal income per year of two-thirds of mankind. An elimination of these conflicts would enable these funds to be spent on minimizing the suffering from deprivation of the majority of mankind. Pauling suggested that scientists and scholars should begin to formulate a practical schedule of progress toward the goal of such transfers. He said that it was only the intellectuals and scientists of the world who could analyze this problem in a sufficiently thorough way; they should take political actions as individuals, as science advisers, as educators and by applying pressure on governments and voters.

After 1969 when Pauling spoke, there was a formulation of what is called the New International Economic Order, which was adopted in 1974 by the 6th Special Session of the UN General Assembly. Unfortunately, just after these proclamations were made, came the increase in oil prices and rise of the monetary politics. Few people today remember the work, which was done on the international economic order. But, in any case, to my knowledge, not much thinking went into emphasizing Pauling's ideas of world taxation. I have now come to believe that Pauling's idea was one of the most important ideas, which came out of the last decade. It seems to me a great pity that it was not given a proper economic formulation by the economists of the world either from the rich or the poor nations, and that the concept of world international taxation has not become common currency to replace aid commonly thought of as charity and which in the ultimate analogies depends on the vagaries of national governments.

One of the few who have discussed this issue in recent times is again Willy Brandt who said in 1980 in the introduction to his Commission's Report: "It is our conviction that we will have to face more seriously the need for a transfer of funds ... with a certain degree of automaticity and predictability disconnected from uncertainties of national budgets and their underlying constraints. What is at stake are various possible forms of international levies." "Why should it be unrealistic," he asks, "to entertain the idea of imposing a suitable form of taxation on a sliding scale according to countries' ability? There could be even a small levy on international trade, or a heavier tax on arms exports. Additional revenues could be raised on the international commons, such as sea-bed minerals."

Brandt advances the idea of "international commons" as a prelude to full-fledged taxation. That certain resources of the seas should be declared as belonging to humankind as a whole is an idea which the developing countries have espoused since 1968. A Convention to regularize this has now been embodied in a draft for "Law of the Sea" which the UN Conference has recommended all UN states to adopt. This was at Montego Bay, in the last days of December, after nine years of patient negotiations marked by a willingness to

compromise as a necessary part of the search for a larger solution. One hundred and nineteen nations have so far found it possible to overcome their individual reservations and marginal disappointments and sign the instruments, which make the Law of the Sea a new international fact of life, giving substance to a "Sea Bed Authority" which will be sited in Jamaica.

The US Government, however, has decided to stand out and vote against adoption of the recommendation. This decision was taken by the Republican Administration in 1981, repudiating the skillful negotiations by the Carter Administration to arrive at a compromise formula for the draft convention. After the US had decided to back out on the Carter Administration's pledges, Britain too has decided to stand out. Since these two nations represent a substantial slice of the world's economic power and technological capabilities, their decision to stand out in the interest of their multinationals can be a very serious wrecking maneuver indeed.

In this context the remarks of Mrs. Jean J. Kirkpatrick, the US Ambassador to the UN, on March 3, 1983, are significant. Writing in a journal on Regulation published by the American Enterprise Institute, she complains: "The UN regulatory initiatives extend quite literally from the depths of the oceans to the heavens, from the Law of the Sea Convention to an Agreement Covering the Activities of State on the Moon and other Celestial Bodies." According to her, the US balked at signing the Law of the Sea Convention which required that mining companies and other undersea ventures be licensed by a new international authority, pay what would amount to royalties to it and be bound by its decision on production and the like. In Mrs. Kirkpatrick's view, the big push within the UN stems from a sort of class-welfare, poor nations versus rich with regulation as a weapon for the redistribution of wealth. According to her, this type of thinking guides many of the participants in a UN political process. "There is a good deal of vote-trading, arm-twisting, demagoguery, playing to the galleries, and the result is that proposed agreements which are supposed to benefit all nations often turn out to be, above all, instruments for global redistribution of wealth and a new global paternalism. In a world body of 157 nations, the US and the capitalist West are an outnumbered automatic minority. The UN agencies then are the scene of a struggle that we seem doomed to lose. The international bureaucracy functions as the new class to which power is to be transferred. Global socialism is expected and, from the point of view of many, is the desired result." As her remarks clearly show, there is an urgent task for us, particularly the intellectuals from developing countries, to invest the idea of International Commons with a theoretical basis so that it comes to be accepted by the populations of the developed countries.

One way to make these ideas more acceptable may be to declare that these commons will be used only for global tasks. And among these urgent global tasks is the application of science and technology to global problems. If, for example, these International Commons were used for building up research and

development capabilities, now sadly neglected, in the sphere of energy and in the sphere of environment, there may be less opposition to these than there has been.

To take the case of environmental tasks, everyone speaks of the degradation of the biosphere. People speak of the disappearing rain forests and the imminent disappearance of large numbers of animal and plant species. The Report "Year 2000" commissioned by President Carter states that "in the next 17 years, 1/4 million plant and animal species will disappear because the developing countries will be forced to cut their forest wealth in order to make up for scarce fuel and in order to grow more food." One may in this context ask if it is not the concern of the environmental groups also in the developed countries to help to preserve this global heritage? Should they not come to the rescue of the developing countries? Should this type of global assistance not be a first charge on the International Commons?

As a scientist, I would like the International Commons used for research on global scientific problems. This was one of the suggestions made at the Vienna Conference on Science and Technology in 1979. The global problems suggested were research on diseases of the developing countries, research on greening of deserts, research on weather modification particularly for developing countries, research on alternative energy, research on productivity of marginal soils, research on earthquake predictions and the like. Recently, in December 1982, there was a meeting of chemists – Chemrawn – held in the Philippines on the subject of Chemistry and Development. We at Trieste are going to hold a Conference on Physics and Development in 1984 in conjunction with IUPAP. I hope many of the ideas expressed at these forums for further research do not fade away for lack of resources.

Perhaps I should mention Masaki Nakajima's "Dream for Mankind". In Table 2 is his list of global super-infrastructure projects, which may constitute elements of a "Global New Deal"; the implementation by the richer nations of the super projects would lead to stimulation of constructive demand in manufacturing industries, as well as technological incentives, in lieu of arms production. Hopefully, this would be accompanied by increase in GNP and employment opportunity both in developed and developing countries. According to Nakajima, "Now is the time for mankind to exert a bold, new and brave, long-range vision, a vision which transcends narrow short-term national interest. As the Prophet-King Solomon said in the Bible: "Where there is no vision mankind perishes."

Science for Peace and Progress
TABLE 2

Name	Nations (Areas) involved	Outline of the Proposal
1. Greening of deserts	North African nations and Arab States	Greening of the deserts in the Sinai and the Arabian peninsula.
2. Collection station for solar heat		Erect a large-scale installation for the collection of solar energy in a remote part of the World. Total investment in land, pipelines, and accessory equipment would reach \$20 to \$50 trillion. Its total annual output would be equivalent to 200 billion barrels of oil.
3. Electric power generation using sea currents		There are 12 promising areas along undeveloped ocean shores extending from the equator to the temperate zones. Maximum generating potential of one area, 35 million kW. Total for 12 areas about 200 million kW.
4. Himalayan hydro-electric project	India China Bangladesh	Damming of the Sanpo River on the upper reaches of the Brahmaputra in the frontier area between China and the Indian province of Assam to make it flow into India through a tunnel across the Himalayas. Potential generating capacity 50 million kW in maximum 37 million kW in average. Annual generating capacity 240 billion to 330 billion kW.
5. African central lake	Central African nations	Control the flow of the Congo River by building a dam to create a vast lake in Congo and Chad regions of Central Africa to improve natural conditions in the area.

It is the grand vision behind these projects which is so commendatory and it is this global vision which alone will solve our problems of the future.

To summarize, I would like to see the ideas of world taxation brought into the sphere of fundamental economic thinking. As a prelude to this, I would like to see the ideas of International Commons and the sharing of global resources (for example, the riches of the seas, and of the Antarctica) taken up vigorously on a theoretical, as well as at a political level – for example, at the Summit Conferences.

Personally, I would like to see these Commons expended on scientific research on global problems in the first instance. I would like to see much greater emphasis given to the global programs like International Geophysical or Biospherical Programs which, at the moment, organizations like ICSU undertake on a meager budget with contributions from the not too affluent UN bodies like UNESCO. As an example of joint scientific projects, there are the programs of collaborative research for European nations like the fusion research program and laboratory at Culham in the UK, or the European Molecular Biology program and laboratory at Heidelberg. On the other hand, there are very few global laboratories for global problems research. These should be the first charge on the International Commons.

I have been speaking about a theoretical basis for international taxation based on well-reasoned appeals to economic self-interest and to man's rationality. However, as the great religions of the world teach us, in the end the most potent human actions stem from man's ethical sense. I am a firm believer in man's moral and spiritual state and I shall conclude with the words of a mystic who thus expressed the international idea of Family of Man in the 17th century – John Donne: "No man is an island entire of itself; every man is a piece of the continent, a part of the main. If a clod be washed away by the sea, Europe is the less, as well as if a promontory were, as well as if a manor of thy friend's or of thine own were. Any man's death diminishes me, because I am involved in mankind; and therefore never send to know for whom the bell tolls; it tolls for thee. ..."¹ ■

¹ The original text of John Donne (1573-1631) is as follows: "No man is an *Iland*, intire of it selfe; every man is a peece of the *Continent*, a part of the *maine*; if a *clod* bee washed away by the *Sea*, *Europe* is the lesse, as well as if a *Promontorie* were, as well as if a *Mannor* of thy friends or of *thine owne* were; any mans *death* diminishes *me*, because I am involved in *Mankinde*; And therefore never send to know for whom the *bell* tolls; It tolls for *thee*. ..." (Passage from "Devotions Upon Emergent Occasions", 1624)

27

Beam Weapons in Space

It is still a matter of wonder how the Martians are able to slay men so swiftly and so silently. Many think that in some way they are able to generate an intense heat they project in a parallel beam against any object they choose by means of a polished parabolic mirror of unknown composition, much as the parabolic mirrors of a lighthouse projects a beam of light. However it is done, it is certain that a beam of heat is the essence of the matter. Whatever is combustible flashes into flame at its touch, lead runs like water, and water (instantly) explodes into steam.

— H.G. Wells in *The War of the Worlds* (1898)

1. *Military Capabilities of Space Satellites*

"The romantic image of spacecraft unraveling the mysteries of the unknown has diverted people's attention from their military function." Few realize, for example, that since the first military satellite was orbited more than twenty years ago, nearly 2,500 spacecrafts, or some three-quarters of all spacecrafts launched, have circled the Earth for military purposes — "reconnaissance, communications, navigation, weather forecasting and early warning of an attack by enemy missiles." One military satellite is launched every third day and space has become a crucial environment for modern defense and offense, so far as the strategic doctrines of the superpowers are concerned. Thus, if the military satellites of one superpower were destroyed, its military capability would be drastically curtailed. This is because artificial Earth satellites are the essential eyes, ears and nerves of the fighting forces of today. Satellites orbiting close to the Earth identify potential military targets and determine their precise location. They not only relay military messages, but are also able to guide modern missiles, aircraft and naval vessels carrying lethal nuclear and conventional weapons to their targets with almost pin-point accuracies. The crippling or destruction of one or more satellites by the enemy would be tantamount to a declaration of war: "War on Earth could thus start in space."

Taking into account of these potentialities, both superpowers are developing anti-satellite (ASAT) weapons and are investigating methods of destroying each other's satellites as well as nuclear missiles. These include weapons which up to now were in the province of science fiction. Among these are high-energy laser

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(light) beam weapons (LBW) and electron, proton or neutral hydrogen particle-beam weapons (PBW). Neither side has deployed such weapons in space so far, but there is no doubt that enormous efforts and funds are being spent on their development. This paper will consider the prospects of such weapons for the missions they are supposed to carry out. Such an assessment of the potential of these weapons is also necessary for the following reason.

Advances in beam weapons technology have contributed significantly to the current change of thinking among some military planners away from policies of "Mutual Assured Destruction" (MAD) to policies which actually consider the waging of and hoping to win a nuclear war a distinct possibility. This has aroused fears in some quarters that such thinking may nullify the military credibility of the MAD dogma and may produce an instability leading to possible pre-emptive strikes. If the difficulties of deploying beam weapons are widely and soberly understood, such fears may possibly be lessened.

2. Beam Weapons

Directed beam weapons function by depositing on a target, missile or satellite, energies of 1 kilo joule or more. An energy impact of this magnitude will, in general, create serious secondary thermo-mechanical effects in the target which will be destroyed or will malfunction. This energy would be delivered in an incredibly short time by the beam weapons. A laser or a particle beam travels with velocities of 300,000 km/sec. while the target missiles or satellites have velocities of the order of 1-7 km/sec. Thus, fired from 1,000 km away, the beams could strike the target in milliseconds, during which the target would have moved no more than a few meters. However, the destructive beams must actually hit the target; this is in contrast to explosive warheads which can be lethal at considerable distances.

One consequence of such short timings for deployment of beam weapons (seconds) as compared to the deployment of the 'lumbering' ballistic missiles (minutes) is that decision-timings will also be in the range of seconds rather than minutes.

To go back to the uses of the beam weapons, one of the likely uses would be placing them in outer space on board a satellite some 1,000 km above earth. Such a beam weapon could be used in an anti-ballistic missile (ABM) mode by firing at missiles during their boost phase. In this phase, the missiles are considered relatively easy to locate and to track because of their limited angular movement. A relay of some fifty satellites would be needed to cover all launching sites; a single satellite would have to be capable of destroying some 1,000 missiles during their boost stage which may last around eight minutes. Satellite-based beam weapons may also be deployed in an anti-satellite (ASAT) mode to attack other satellites.

Alternatively, beam weapons may be earth-based. Such earth-based weapons may have applications in conjunction with space-based vehicles, the beams being reflected from mirrors mounted on the space-satellites.

3. *A Description of Beam Weapons*

To be of practical use, a beam weapon must be capable of destroying, diverting or immobilizing a missile launched by an enemy, well before it arrives over the territory to be defended. As stated above, two main beam weapon types have been considered. The first is aimed at destroying intercontinental ballistic missiles soon after launch and so is mounted in an orbiting satellite and requires a range of at least 1,000 km plus rapid aiming and firing capabilities in order to cope with some 1,000 missiles in the eight minutes or so of the boost phase available. The second type is ground-based, having as target, missiles (or warheads) after their re-entry into the atmosphere. For these purposes a range of about 1 km is claimed to be sufficient. For a satellite-mounted system, the only possibilities are neutral particle beams or lasers. However, existing neutral beam machines give less than a millionth of the power that would be required for an effective weapon and yet weigh thousands of tons. The situation regarding lasers is similar. Let us consider the two types of weapons in detail.

3.1 *Laser Beams*

Laser beams are intense streams of electromagnetic waves, all of the same frequency, phase and direction of motion. The waves are coherent. The energy output of a laser can be thousands or millions of joules, emitted in very short bursts of millionths or a few billionths of a second.

In the atmosphere a laser beam is amputated particularly in dust, fog or thick haze. Even in cool dry air, its intensity is degraded by one half in four kilometers. However, the propagation of a beam in vacuum is unobstructed except for a small divergence of the beam. Thus, laser beam weapons are primarily suited to operate in outer space.

3.2 *Charged Particle Beams*

In case of a ground-based system (assuming that lasers cannot be used because of their vulnerability to weather conditions) the suggestion has been made that one may "bore a hole" in the atmosphere with charged particle beams; for example with a pulsed electron beam, in the same fashion as a lightning-strike bores a hole in the atmosphere. Again, existing machines give output-beams thousands of times lower than what would be required even under the most optimistic assumptions. Charged particle beams (electrons or protons) cannot be used in weapons mounted on satellites orbiting the earth for several reasons. One is that, due to space charge effects, a charge particle beam increases in diameter exponentially, and so could not be focused onto a distant target. Secondly, a charged particle beam would be deflected by the earth's magnetic field. For example, a beam of 1 GeV protons (an energy which has been proposed as

suitable for a beam weapon) mounted on a satellite, crossing the earth's magnetic field at right angles, would describe a circle of about 100km radius. Thus charged particle beams would be restricted to trajectories nearly parallel with the earth's magnetic field. Since the field distribution in space is not well known, the deflection due to the earth's magnetic field could not be calculated accurately.

3.3 Neutral Particle Beams

The next possibility to consider is the use of neutral particle beams. There is no known method of making closely focused intense neutron beams, but it is possible to make focused atomic hydrogen beams. This is done by accelerating negative hydrogen ions (a hydrogen atom with an extra electron), focusing them and then stripping the extra electron off, by passing the beam through a thin foil or layer of gas.

4. Present Shortcomings of Beam Weapons:

Energetic and Other Considerations

To see what an impossible task we have in providing such energies, recall that a typical large city power station has power output no higher than 1,000 megawatts (10^9) watts.

4.1 Neutral Particle Beam Weapons

Studies at the Massachusetts Institute of Technology (MIT) have shown that it would require a dissipation of over 3,000 joules per cubic centimeter to melt the aluminum shell of a missile. At the minimum, some 250 joules per cubic centimeter could be sufficient to set off the chemical explosive of an atomic bomb detonator. "Assuming that a beam suffers a divergence of only 10^{-5} radians, the beam radius would be about 10 meters at 1,000 km with this radius, even at the minimum, if we consider detonating an explosive covered by a thin skin of aluminium, the beam energy required to set off the explosive would have to be in the region of 5×10^9 joules and to melt aluminium one would need ten times this." A ballistic missile would probably be traveling at about 1km/sec when it leaves the earth's atmosphere, and so would pass through the beam in about 10ms. An energy of 5×10^9 joules in 10ms represents 5×10^{11} watts (a hundred thousand megawatts).

Consider the present state of the art in negative ion laboratory accelerators which would be needed to provide such beams. "The highest power accelerator of this type in existence is TRIUMF at Vancouver, Canada. It can produce energies *less than a millionth of what would be required* from the above calculation," and this accelerator weighs over 4,000 tons and consumes about 5MW of electrical power. "The highest peak current negative ion accelerator is the Fermilab injector, which can give up to 30-milliampere beams at 200 MeV, but with a maximum pulse length of 60 microseconds and a beam divergence

about a hundred times that assumed in the calculation above." This accelerator is about 200m long and requires 35MW of radio frequency power during the pulse. Thus, it can be seen that in the laboratories in the public domains we are many orders of magnitude below the performance required for a neutral beam weapon so far as the United States is concerned. To our knowledge, the situation in the USSR is the same.

4.2 Laser Beams: Energetics, Fuel Requirements and Alignment Accuracy Needed

The same considerations hold for laser beam weapons, even more so.

To damage a missile, a laser beam would need to provide a sufficient energy density to melt a hole in the casing. "A bright metal casing will reflect short pulses of laser beam up to a certain density, of the order of 10^6 watts/cm² at about 10^7 watts/cm², a laser beam drills holes in metal at the rate of about 1 mm per millisecond. It may be possible to achieve a beam divergence of about 5×10^{-5} radians, giving a beam diameter of about 10m at 1,000 km. However, to get a power density of 10^7 Watts/cm² over this area would require a total power of about 10^{14} Watts. If we assume a pulse length of about 5ms (to penetrate a 5 mm skin) then the total energy required in the beam is about 5×10^{11} joules."

The largest laser arrangement now in use is SHIVA at Livermore, giving beam-energy totaling 2×10^4 joules. "At the same laboratory, a more powerful assembly, NOVA is under construction, which will give a total of 3×10^5 joules. The hope is that one day, 10^7 joules may be reached. That would still be more than four orders of magnitude too small. Recall that NOVA is about 200m long and will cost about 200 million dollars. And, once again, in the USSR, there appear to be significantly no more powerful laser systems, to our knowledge."

The fuel requirements of a laser weapon represent another obstacle. A hydrogen-fluoride laser would consume 660 kg of fuel for each missile destroyed. To shoot down 1,000 missiles, each satellite will need to be supplied 660 tons of fuel (20 loads for the US space shuttle).

To ensure the energy needs of the laser weapon, a combination of nuclear power plant and rotor storage has been suggested, but the consequences on the satellite attitude of suddenly decelerating a multi-ton high-speed rotor (or even two contra-rotating ones) appear not to have been considered.

Further, as remarked earlier, it is necessary to make a direct hit with a beam weapon, unlike an explosive anti-missile weapon, where a proximity fuse can be used to set off the explosive, nuclear or chemical, if the aim is sufficiently good to put it within the range at which the blast can damage or deflect. Taking the 10m radius beam size assumed above, at 1,000 km the alignment error has to be less than 10 micro-radians, or about 2 seconds of arc. "This is about a factor of 1,000 better than needed for an anti-missile rocket fitted with a nuclear warhead. Thus, the tracking radar on the satellite would need to be able to locate the missile to this accuracy, and then the beam would have to be aimed, either by rotating the whole satellite in two planes, or moving some beam steering device

(either magnets or mirrors) relative to the satellite." Even working from a fixed base it would be very difficult to locate the missile and aim to the required accuracy in the fraction of a second, assumed to kill 1,000 missiles in eight minutes or so. To do so on a satellite, where every movement will have its corresponding reaction, seems well nigh impossible.

Other difficulties are that if a hit is not achieved, there is no means of determining the direction or distance of the miss, to correct the aim for the next blast; the target would have to be identified amongst many decoys, and the aiming radar would be subjected to jamming.

4.3 Costs

What about the costs of such weapons?

The cost of a unit can hardly be assessed reliably from present extrapolations, but it is likely to be in the billions of dollars range. In addition, the unit weighing hundreds of tons, would need to be assembled in space. "With the Space Shuttle, it is estimated the present price of 10 million dollars per ton to put a satellite into orbit, will fall to 4 million dollars per ton, but a 100-ton satellite would still cost 400 million dollars to put into orbit." The number of units which would be needed would be a minimum if they were to be put into geosynchronous orbit, about 36,000 km above the earth's surface. However, the range would then be thirty-six times that assumed in the above calculations, requiring more than a thousand times the power for the system. If one considers an orbit only about 1,000 km high, for which the satellites would move rapidly with respect to the earth's surface, one would need about fifty active units to ensure that at least one satellite would be in the appropriate position to cover all the possible launching sites available to an enemy at all times (plus spares needed for failing satellites).

Thus, such an anti-missile system would involve a minimum cost of many hundreds of billions of dollars, plus of course the costs of the geostationary satellites for command and control.

4.4 Charged Beam Weapons

The neutral-beam and laser systems, which, as shown above, are the only types that could be considered for satellite-based weapons, are all but useless at ground level for killing nuclear missiles. For the ground level, this leaves charged particle beams. "The main problem with these is scattering by the air molecules. A simple calculation shows that an electron beam of 1,000 amperes at 1 GeV would expand to greater than 80m radius at a distance of 1 km." A similar proton beam would be dispersed even in a shorter distance in a few tens of meters. The proposers of such weapons have suggested that a rapid sequence of beam pulses could "bore a hole" in the atmosphere, by reducing the density by local heating, and forming a plasma tube through which the subsequent pulses could propagate. Calculations have shown that, under ideal conditions, without any instabilities, "it would take about 1.5×10^6 joules to bore a hole, 1 cm² cross-section and 1 km long, but that the beam size would increase by over four times over this distance"

so that the energy required would be much greater, about 10^7 joules. With a 1 GeV, 1,000 ampere beam assumed previously, it would take 100 pulses of 0.1 microsecond length to deposit this amount of energy and to form the channel. This means that the ground accelerator, accelerating the charged particles would have to provide a mean power of 1,000 megawatts during 10-15 milliseconds. Even if such power levels could be provided, it is unlikely that an ionized channel in the atmosphere would propagate in a straight line, due to instabilities as shown in lightning strokes, which often follow paths differing considerably from a straight line.

5. A "Fatal" Flaw in the Concept of Beam Weapons in Space

But even if all these problems can be solved, there is a serious flaw in the entire conceptual basis of these weapons which was pointed out by W.J. Broad in the *Science Magazine* in its issue of March 12, 1982. These exotic weapons could easily be destroyed by a single nuclear blast in open space.

"Such a blast would instantly set up an electric pulse of upto a million volts per meter in hundreds of satellites and battle stations, disabling them and replacing the bold vision of a Star Wars conflict with the dreary reality of a nuclear graveyard. A 2-megaton blast just outside the earth's atmosphere would set up a pulse in objects as far away as geosynchronous orbit, some 36,000 km above the earth. The effects of a larger bomb would reach even further."

Even though one knew since the early 1970s that satellites could be damaged by a nuclear pulse, new strategic realities are beginning to make the threat more worrisome. A nuclear blast in outer space sends out in all directions an immense number of prompt gamma rays and x-rays. On earth, such radiation is quickly attenuated by the atmosphere. But, when these radiations strike a metal object in space, such as a satellite, "they knock out Compton electrons, creating a charge imbalance in the skin of the satellite and setting up extremely high electric fields - on the order of 100,000 to 1 million volts per meter." These surface fields induce large currents and voltages in the electronic payload, causing disruptions and burnouts. It is as if the delicate semiconductors that lie at the heart of a satellite were suddenly hit by a bolt of lightning. The distance over which this effect can occur are immense, "an unprotected satellite suffering equipment upset from a 1-megaton nuclear blast some 25,000 km away." The closer the satellite or battle station to the blast and the greater the yield of the weapon, the larger and more damaging is the pulse.

Technologists who still want to try to protect space hardware have not given up hope, but they paint a gloomy picture. Rather than trying to build protection into valuable satellites, the emphasis is now shifting to taking them completely out of the danger zone. "A satellite equipped with special sensors and engines might be able to detect a nuclear-armed killer satellite thousands of kilometers away and kick itself into a distant orbit so as to avoid the damaging rays from the blast. From there it might still be able to perform its critical mission. Defense

officials admit the concept is technologically difficult, but they also note the lack of easy alternatives."

6. Conclusions

I must make it clear that the figures and the quotations in this paper have been taken from the writings of 1) A.M. Din (Institute of Theoretical Physics, University of Lausanne) from his article *Outer Space, A New Dimension of the Arms Race*, edited by B.M. Jasani and published by SIPRI, Stockholm (1982); 2) from a memorandum prepared by M.C. Crowley-Milling of CERN, Geneva; 3) from a paper of W.J. Broad in the *Science Magazine* – the prestigious journal of the American Association of Advancement of Science, Washington, in its issue of March 12, 1982; and 4) from a paper of Kosta Tsipis in *Scientific American* of December 1981. Tsipis participated in a series of workshops organized by the Program in Science and Technology of the Physics Department of MIT. Except for Din, the conclusions of the other authors are pessimistic. Din, however, adduces the example of the development of nuclear weapons; no one, even in 1939, when nuclear fission was discovered, would have expected that in six years, atomic weapons would be a reality. He infers that if a superpower is totally committed, with a committed scientific community backing it, and with unlimited funds to spend (a total over the years approaching a trillion dollars – some one-third of the combined GNPs of the two superpowers), it may be possible to make a dent on the problems mentioned in this note and 'acceptable' (though not 100% effective) beam weapons systems may be deployed in 15-20 years.

However, those of us who want mankind's resources spent on world development can only ask in despair: are there really such irreconcilable differences among the super powers which call for these outlays, for a project which, in any case, can never eliminate with hundred percent effectiveness the danger of nuclear devastation of the earth? Is there no other way that mankind could agree on, against nuclear devastation? Is there no way that instead there may be international collaboration in harnessing the scientific and material resources of such colossal magnitudes, for human development – for elimination of want, famine and disease in the South and degrading and soul-destroying joblessness in the North? ■

28

The Role of Science in International Development

On behalf of the Society's Chapter of the Friuli-Venezia-Giulia region, it is a very great pleasure for me to welcome the European meeting of the Society for International Development (SID) to the International Centre. Trieste is a town which has taken upon itself the tasks of helping with international development through Science, particularly in the developing countries. Since bringing about an awakening to the role of Science in development is also one of the major aims of the Society, I am appreciative that the Society chose to meet here at the Centre in Trieste. This meeting will acquaint our guests with the initiatives Trieste is taking in this regard, with the Government of Italy's active help, and with the UN participation through this Centre. We are privileged to welcome one thousand scientists every year from developing countries in all disciplines of Physics – pure and applied, as well as the proposed UNIDO Centre. On our side, it will no doubt give our assembled scientists newer perspectives in the tasks in our countries.

There is no question but that the developing world is in a terrible situation at present. The disaster of the Ethiopian famine is merely a symbol of this. There are other indicators equally dire at which one may point. Take peace and security; since the end of World War II, there have been one hundred and ten conflicts in the world, almost all of them fought on the soils of the developing countries. At the present time, twelve such conflicts are raging, almost all in the Third World, with at least half of them with direct or indirect involvement of the Super Powers. The loss of security and the misery these conflicts entail can be gauged even at a Centre such as this, which devotes itself to physics. Frequently we are called upon to welcome scientific refugees from these countries in which these wars are being fought. And then there is the economic bankruptcy of the Third World, brought about not because of our countries' profligacy, but principally because of any lack of progress on ideas to which this Society has made fundamental contributions – like the New International Economic Order with its insistence on fair prices for developing countries' commodities. Altogether, the developing world is a very unhappy place to live in.

You have assembled to discuss today what role Europe can play in alleviating some of these problems. In this respect, I personally have a number of

Talk at the Opening Meeting of the Society for International Development (SID), Trieste, Italy, January 18, 1985.

roles; first, as a citizen of a developing country; second, as directing a United Nations institute of Science designed for developing countries' scientists which is situated in an oasis of peace and tranquility in Europe, through the generosity of a hospitable country and a hospitable town; and, thirdly, as a member of a European chapter of SID. Thus, whereas on one hand, I must highlight the achievements of Europe and Italy in particular in respect of assisting development, I will also be frank and critical from the point of the developing countries and their perceptions of Europe's role.

There is no question but that some of the individual European nations have impressive records of help to, and have distinguished themselves by displaying a real feeling for, developing countries. To take one index of this in terms of aid, Norway, Holland, Sweden, France and Denmark already exceed the .7% target, recommended by the United Nations, with Belgium reaching .6% and West Germany reaching .5%. There are countries which have not attained this target (or they once did and are now falling behind), like Britain with .35, Switzerland .31, Italy .24, Austria .24. But even the last two countries (Austria and Italy) – which started only recently – reach the figures registered by USA with its present .24%. (Recall that at the time of the beginning of the Marshall Plan the US was giving an aid amount of 2.79% of GNP.)

But notwithstanding this commendable generosity, forgive me for saying this: When one hears of the scandal of the grain surplus either accumulating at mountainous cost to European tax-payers and then being made available to some Eastern European countries for feeding their cattle, when one hears of Europe not putting its political weight behind correcting the imbalance of commodity versus industrial prices, one gets the perhaps wholly unjustified perception from developing countries of the passivity of European help – at the least, of not thinking about these issues in a coherent manner. I mentioned farm surpluses which bankrupt EEC. The other side of the coin is that five hundred million people on this Earth (one in nine) are severely malnourished; ¼ million children will die this week from diseases related to malnutrition, while a third of the world's food grains – four hundred and fifty million tons – are fed to livestock to provide high protein food for the lucky few. In this respect, I may be permitted to quote the EEC Court of auditors itself as quoted in *The Economist* of London this week. This Court has severely criticized the administration of humanitarian aid from EEC. According to *The Economist*, in their 1983 financial report, they bluntly state that aid frequently arrives late or at the wrong time. "By the end of December 1983, some of the countries in greatest need of aid (Tanzania, Zambia, Ghana, Somalia, Sri Lanka and Madagascar) had not received any of the aid promised to them under the 1983 program. Altogether, only 42% of the cereals, 36% of the milk powder, and 26% of the butter oil the Commission had intended to send was actually delivered."

I have started with these critical remarks on matters which are economic or political – both areas where I have no particular expertise. Forgive me for

bringing them up; but I shall now turn to my proper sphere, as a scientist, and concentrate on science-related problems. The plea I wish to make is in respect of Europe taking a concrete lead in building up of scientific infrastructure of developing countries.

I do not have to tell this audience of the value of harnessing science and technology to the problems of development. There is no question but that the modern interdependent world and most of its problems have basically been brought about by the physicist who has created the communications system and by the chemist and the biologist who created the penicillin and fertilizer revolutions. There is no question but that the developing world's problems can only be resolved by harnessing and investing in science and technology.

Now Science and Technology do need investment for their deployment. But first and foremost they need scientists and technologists – trained scientists and technologists. There is, however, scant movement to build up trained scientific communities in our countries. Even worse, while the need for technologists is recognized, the need for scientists and for science transfer is not even appreciated in the developing world. Thus, barring a few of its countries – Argentina, Brazil, China and India – the Third World, despite its recent realization that science and technology are the sustenance, and its major hope for economic betterment, has taken to science – as contrasted even to technology – as only a marginal activity. I would not bring this point up today, but it happens to be true of the aid-giving agencies of the richer countries, of the agencies of the United Nations and also, unfortunately, of the scientific communities of the developed countries which might naturally have been expected to be the Third World scientists' foremost allies in this crusade for more science.

Why am I insistent that science in developing countries has been treated as a marginal activity? Two reasons.

Policy makers, prestigious commissions (like the Brandt Commission), as well as aid-givers, speak uniformly of problems of technology transfer to the developing countries as if that is all that is involved. It is hard to believe but true that the word "science" does not figure in the Brandt Commission report. Very few within the developing world appear to stress that *for long-term effectiveness, technology transfers must always be accompanied by science transfers*; that the science of today is the technology of tomorrow and that when we speak of science it must be broad-based in order to be effective for applications. I would go even so far as to say: if one was being Machiavellian, one might discern sinister motives among those who try to sell to us the idea of technology transfer without science transfer. There is nothing which has hurt us in the Third World more than the slogan in the richer countries of "Relevant Science". Regretfully this slogan was parroted in our countries unthinkingly to justify stifling of the growth of all science.

It is not clearly understood that science transfer is effected by and to communities of scientists. Such communities (in developing countries) need building up to a critical size in their human resources and infrastructure. This building up calls for wise science policies, with long-term commitment, generous patronage, self-governance and free international contacts. Further, in our countries, the high-level scientist must be allowed to play a role in nation-building as an equal partner to the professional planner, the economist and the technologist. Few developing countries have promulgated such policies; few aid agencies have taken it as their mandate to encourage and help with the building up of the scientific infrastructure.

In my remarks, I wish to concentrate on just this one problem. I wish to suggest that one sphere of action for Europe is to place emphasis on the building up of scientific infrastructure in their aid policies and also to create institutions for developing countries on the lines that the Government of Italy has done in supporting this Centre for Physics or the UNIDO Centre for Biotechnology.

To illustrate my remarks, I will mainly be concerned with the new areas, not adequately covered so far, concerning the sciences of energy and scientific ecology. The need and value of creating institutions for scientific training and research in these disciplines is well recognized. For example, Dr. Henry Kissinger, as US Secretary of State in 1974, committed the US Government to setting up a multiplicity of institutions to meet the needs of cooperative world development. Two of these were: 1) A "Development Security Facility" to stabilize prices of commodities against crude cycles of export earnings though "indexing" was decisively ruled out; 2) Measures to improve access to capital technology and managerial skills – and in particular an International Energy Institute, an International Centre for Exchange of Technological Information, and an International Industrialization Institute.

He prefaced the need for such institutes by the remark: "Over the remainder of this century, ... the division of the Planet between North and South could become as grim as the darkest days of Cold War. We would enter an age of festering resentment, of a resort to economic warfare, a hardening of new blocks, the undermining of cooperation, the erosion of international institutions – and failed development."

None of these promises of these institutes has been kept. I saw Dr. Kissinger in 1983 in Morocco. I reminded him of these promises – particularly the promise in respect of the Energy Institute. He said – Write to me. I did. He graciously acknowledged and that's that.

Why am I stressing the role of one or more Energy Institutes? Every economist knows that the less developed countries with $\frac{3}{4}$ of the world population consume only 12% of the world's supply of energy, while the developed countries with $\frac{1}{4}$ of its population consume 80% of the total. And this imbalance is increasing with the fuel prices escalating. During President Carter's

days, the US started to emphasize non-conventional energy research for the US. A by-product would have been provision of research for energy needs of developing countries also. A UN Conference was held in Nairobi but, the conference notwithstanding, to my knowledge, there still does not exist an International Centre for Energy Research and Training on the scientific side for developing countries and their scientists. What is needed is a Centre which should emphasize basic hard Science in this area. To quote the *London Economist* again. In its issue of September 27, 1980, it had this to say on the subject: "If solar energy is to provide the solution to the world's fuel crisis, that solution will not emerge from low-technology roof-top radiators. A breakthrough (will) come from applying quantum physics, biochemistry or other sciences of the 20th century. Today's technology-based industries all depend on new science."

Thus, without a good base in solid state and material sciences, there is no hope whatsoever of making good. An optical converter must make use of as little material as possible; how little is determined by the penetration depth of the solar light and drift length of the excited state on which the conversion is based. For an amorphous material this depends on the density of defects and an understanding of these. Efficient and cost-effective photovoltaics thus depend on physics of solid state materials and not on a technologist's tinkering. To fill part of the need, the Trieste Centre has felt that it should develop and concern itself with high-level physics of energy-related materials, and in particular, with physics of absorbing and emitting surfaces. So far our Colleges in this field have had participation of around one thousand physicists. But Colleges every second year are no substitute for a full-fledged Energy Institute for developing countries.

I would like very much a World Institute for Energy, for solar energy, for photovoltaics and the like - to be one of the priority items to be created by European action.

The second area in which I would like to see action on the scientific front is in Ecology and, in particular, in the area of Climate Studies. I do not know whether practically one can hope to change the climate; but surely it is a scandal that there is no scientific study of the climate of the Sahelian area over a long term period. The universities in these regions have their Physics and Meteorological Departments but these Departments are weak, ill-organized and without any funds. They should be made stronger. We at this Centre are trying to take steps to ameliorate this situation but once again, this will be one among the many subjects studied here. I would wish for a new European organization devoting itself to raising the scientific standards of the disciplines concerned.

Another area in which action is needed is the one highlighted by the International Union of Pure and Applied Chemistry in the field of fertilizers. As we all know, the total world population by the end of this century will have grown from four to six billion people, while the world's area under agriculture

will increase only by 4%. In December 1982, in the Philippines, six hundred top-ranking chemists of the world met and drew up a plan of action where chemistry could be utilized to raise the food productivity through chemical inputs in fifteen years – by the year 2000 to increase world food productivity by 5%. A number of world institutes for teaching, training and research of chemists from the Third World were to be created. To my knowledge, no start has yet been made.

Continuing with ecology and considering the steady cutting down of the tropical forests, proceeding now at 2% of the forest per annum for firewood or for agricultural land, one of the anticipated disasters is the annihilation of a large fraction of species and organisms which inhabit these forests. Approximately 1.5 million kinds of organisms have been named and classified, but these include only about half a million from the tropics.

Many tropical organisms are very narrow in their geographical ranges and are highly specific in their ecological and related requirements. Thus, tropical organisms are unusually vulnerable to extinction through disturbance of their habitats. In most places, these forests will be gone within the next twenty to thirty years; and with them most of the three million of these organisms.

With the loss of organisms, we give up not only the opportunity to study them, but also the chance to utilize them to better the human condition, both in the tropics and elsewhere. The economic importance of wild species, a tiny proportion of which we actually use, has been well documented. Suffice to say that the entire basis of our civilization today rests on a few hundred species out of the millions that might have been selected, and we have just begun to explore the properties of most of the remaining ones.

The process of extinction cannot be reversed. Its effects can, however, be moderated by finding the most appropriate methods of utilizing the potentially sustainable resources of tropical countries for human benefit. The explicit relationship between conservation and development was well outlined in the World Conservation Strategy, issued jointly in 1980 by the International Union for the Conservation of Nature and Natural Resources, the World Wildlife Fund, and the United Nations Environmental Programme.

In a recent issue of the *Bulletin of Atomic Scientists*, P.H. Ravan has argued that if the West cannot find the means to eliminate real poverty in the ecologically devastated areas, the people living there will topple any Government; be it friendly or unfriendly! Thus, according to him, it is no coincidence that El Salvador is ecologically the most devastated of all countries of Central America and yet "the authors of the Kissinger Report pay no attention to the ecological problems which force peasants to shift to and destroy permanently, through cutting of forest cover, the productivity of their marginal lands." One may in this context ask if it is not the concern of the environmental groups also in the developed countries – of Europe – to help to preserve this global heritage? Should they not come to the rescue of the developing countries?

Should this type of global assistance not be a first charge on the international communities? Can Europe take a lead in this?

I have given you a few examples of scientific global tasks; they could be multiplied, of the need for newer institutions, newer training and research bodies, newer ecological, and scientific organizations. As I asked before, can we recommend that Europe take a lead in projecting such organizations?

While we are dreaming and speaking of such global tasks, not necessarily scientific, let me conclude by mentioning Masaki Nakajima's "Dream for Mankind". He has listed global super-infrastructure projects which may constitute elements of a "Global New Deal"; the implementation by the richer nations of the super-projects would lead to stimulation of constructive demand in manufacturing industries, as well as technological incentives, in lieu of arms production. Hopefully, this would be accompanied by increases in GNP and employment opportunity both in developing and developed countries. According to Nakajima: "Now is the time for mankind to exert a bold, new and brave, long-range vision, a vision which transcends narrow short-term national interest. As the prophet King Solomon said in the Bible: Where there is no vision, mankind perishes." As the great religions of the world teach us, in the end the most potent human actions stem from man's ethical sense. [...] ▯

29

Physics and Excellences
of Life it Brings

The title of my talk tonight is taken from Robert Oppenheimer. He had three types of excellences in mind. For the theoretician, the excellence of new ideas while he attempts to read Allah's design; for the experimenter, the excellence of new discoveries, of the pleasure of the search, of carrying an experimental technique to its limits and beyond; and finally, of the very human desire to spite the theorist. Oppenheimer had these excellences in mind – but also much more; he emphasized the opportunity physics afforded him to come to know internationally a class of great human beings whom one respected not only for their intellectual eminence but also for their personal human qualities – a true reflection of their greatness in physics. And, in addition, he had in mind the opportunities which physics uniquely affords for involvement with mankind – in the parlance of today, in engaging in problems of development and of enhancing the human ideal.

Tonight I wish to speak on some aspects of Oppenheimer's thoughts from a personal point of view. I shall illustrate these by recalling my introduction into research, on renormalization of meson theories, and the excellent men I was privileged to meet while pursuing it. I also wish to speak on excellence through world development as I was asked by the organizers. More precisely, I shall speak on the International Centre for Theoretical Physics, whose creation, under the auspices of the United Nations, I was privileged to suggest in September 1960. The Centre actually came into being only in October 1964 – beyond the cut-off date of this Conference's coverage. However, the ideas that went into the Centre's creation and the battles that had to be won, as well as the physics milieu of the early sixties – with its desire to keep alive the internationalism of the subject, with its emphasis on science rather than technology, and with its perception of brain drain of high level talent, particularly to the United States – do fall within the period covered.

The notion of a Centre that should cater particularly to the needs of physicists from developing countries had lived with me from 1954, when I was forced to

Speech delivered at the Conference on the "History of Particles from Pions to Quarks", Fermi National Accelerator Laboratory, May 1985.

leave my own country because I realized that if I stayed there much longer I would have to leave physics, through sheer intellectual isolation. At the September 1960 Rochester Conference, in his banquet speech, Mr. John McCone, the then Chairman of the US Atomic Energy Commission, made a reference of the desirability of creating international centers in physics. He had principally in mind accelerator establishments, which might be created under joint US/USSR/European auspices. After the banquet, over coffee, I remember a conversation with Hans Bethe, Robert Sachs and Nicholas Kemmer in the beautiful hall of the women's residence at Rochester University. We discussed the practical possibility of such centers being created and came to the conclusion that the simplest would be to think in terms of an international theoretical physics center.

The same month I had the privilege of being able to voice, on behalf of the Government of Pakistan, this visionary ideal, in the form of a resolution at the annual conference of the International Atomic Energy Agency (IAEA) at Vienna. We were fortunate to receive co-sponsorship of the resolution from the governments of Afghanistan, the Federal Republic of Germany, Iran, Iraq, Japan, Philippines, Portugal, Thailand, and Turkey. As the list of sponsors indicates, the setting up of such a center was of interest not only to the less privileged countries but also to some of the developed ones. The hope was that a center of this type, besides providing a venue for collaborative international research for the East and the West, might also help in resolving one of the most frustrating problems that active scientists in poorer countries face – the problem of isolation. Such men, supported by international funds, would come fairly frequently to the Centre to renew their contacts and engage in active research in their fields.

Right from the beginning we received enthusiastic support from the world physics community. Niels Bohr, before his death, expressed his wholehearted support; scientific panels, convened in 1961 and again in 1963 by the Agency's physicist Director General, Dr. Sigvard Eklund, forcefully recommended its creation. Members of the 1961 panel were Aage Bohr, Paolo Budinich, Bernard Feld, Leopold Infeld, Maurice Levy, Walter Thirring; of the 1963 "Three Wise Men Panel", the members were Robert Marshak, Leon Van Hove and Jayme Tiomno.

Unfortunately, there was not the same unanimous response from the atomic energy commissions around the world. At the 1962 annual conference of the IAEA (where those commissions represent their governments), even though the creation of a center was accepted in principle after a divided vote – by and large the industrialized countries voted against, and the developing countries for the Centre – the IAEA's Board of Governors voted the princely sum of \$55,000 to set up an International Centre for Theoretical Physics. The United Nations Educational and Scientific Organization (UNESCO) voted \$27,000. Thus, additional offers of financial assistance from interested member states had to be solicited; of the five received (from the Government of Italy for a center to be located in Trieste, from Austria for Vienna, from Denmark for Copenhagen, from

Bolostan for Lahore, and from Turkey for Ankara), the most generous was the Italian Government's offer of around \$300,000 plus a prestigious building, with Paolo Budinich, Professor of Physics at the University of Trieste, as the moving spirit behind it. This was accepted in June 1963 and the Centre started functioning on October 1, 1964, with a charter for four years. Oppenheimer served on the first Scientific Council of the Centre. In spite of his terminal illness, he came to Trieste, where he helped draft the Centre's Charter. One admired him and his felicity of phrase – even in such legal drafting. Other members of the first Scientific Council were: Aage Bohr, A. Matveyev, V.G. Soloviev, Sandoval Vallarta and Victor Weisskopf. Dr. Alexander Sanielevici, from Romania, was one of the Scientific Secretaries.

Of the Centre and its functioning, I shall speak little tonight, for surely this will be one of the subjects covered by the future conferences in their series. In 1964, when we assembled in Trieste in a rented building, the whole enterprise seemed like a dream. Once again the world's theoretical community rallied around us – plasma physicists as well as particle physicists. We cared not for fads, only for physics. Our goal was to acquire scientific visibility. In this we succeeded. Thus, one year after the Centre's inception, Oppenheimer could comment at the Centre's Council: "It seems to me that the Centre has been successful in these eight or nine months of operation in three important ways. It has cultivated and produced admirable theoretical physics, making it one of the great foci for the development of fundamental understanding of the nature of matter. The Centre has obviously encouraged, stimulated and helped talented visitors from developing countries who, after rather long periods of silence, have begun to write and publish during their visit to the Centre in Trieste. This is true of physicists whom I know from Latin America, from the Middle East, from Eastern Europe and from Asia. It is doubtless true of others. The Centre has become a focus for the most fruitful and serious collaboration between experts from the United States and those from the Soviet Union on the fundamental problems of the instability of plasmas, and of means for controlling it. Without the Centre in Trieste, it seems to me doubtful that this collaboration would have been initiated or continued. In all the work at the Centre of which I know, very high standards prevail. In less than a year it has become one of the leading institutions in an important, difficult and fundamental field."

To continue the story briefly, in the twenty years of its existence, the Centre has flourished, with physicists from one hundred countries, East and West, North and South, ranging over all disciplines of physics – from fundamental physics to physics on the interface of technology, environment, energy, the living state and applicable mathematics. The Centre welcomes around one thousand physicists from industrialized and one thousand physicists from developing countries every year for research courses, workshops and meetings and for conducting research,

for periods ranging from a few months to a few years.² In addition, from a generous grant from the Italian government, we provided one hundred fellowships in experimental physics, tenable at Italian laboratories. We are federated with approximately two hundred institutes, mostly in developing countries. In addition, our Scientific Council selects three hundred physicists (whom we call Associates of the Centre) – these men and women are accorded the privilege of coming to the Centre three times in six years for periods up to three months per visit, at times of their own choosing, provided they are living and working in developing countries. The Centre's current budget is of the order of five million dollars – three millions come from the Government of Italy, one from IAEA, half a million from UNESCO, and the rest from other Government Agencies. The US Department of Energy gives a special grant of \$50,000 for visits of US physicists.

Although in the founding and running of the Centre we have depended on the volunteer help of the world's leading physicists, it remains a sad fact that the physics communities of the developed countries have, by and large, rendered little assistance in an organized form to the cause of physics in developing countries, including the Centre. I wish to stress the word organized lest I should be failing to pay a heartfelt tribute to the continued work of great individuals who have made real sacrifices in this cause.

There is no question but that the real amelioration of the worsening situation for physics research in developing countries lies within the countries themselves and the role of the Centre and any other outside agency can only be to help generate self-reliant communities. But outside help – particularly if it is organized help – can make a crucial difference. This could take various forms, for example, the physical societies could help by donating two hundred to three hundred copies of their journals to the deserving institutions and individuals and by waiving publication charges. The American Physical Society in fact does provide its publications at half cost to thirty-four physicists from thirteen least developed countries. IUPAP has been helping the Centre defray postage costs for distribution of old runs of journals donated by generous individuals. These schemes should, however, be extended by other societies and laboratories also to cover equipment, and in fact CERN has recently signified its willingness to donate some of its used equipment to laboratories in developing countries. Most important, the research laboratories and the university departments in developed countries could finance visits of their staffs to the institutions in developing countries in an organized manner and reciprocally by creating schemes like the three month Associateship scheme we run at the Centre – at the least for their ex-alumni now working at the developing country universities. Leon Lederman has initiated a scheme at Fermilab whereby a number of Latin American experimental physicists are regularly brought over to train them in techniques of

²The 1986 figures were 2,160 physicists from developing countries and 1,440 from industrial countries.

particle physics and ancillary disciplines. And then there are the excellent cooperative schemes of training like the one which T.D. Lee runs for China. These could perhaps be extended to other developing countries.

May I be forgiven for thinking in the following terms: that the physics institutions in developed countries may consider contributing in their own ways, according to the norms of the well-known United Nations formula, whereby most developed countries have pledged to spend 1% of their (GNP) resources for world development. In the end, it is a moral issue whether the better-off segments of the physics community are willing to look after their own deserving but deprived colleagues, helping them not only materially to remain good physicists, but also joining them in their battle to obtain recognition within their own communities, as valid professionals who are important to the development of both their countries and of the world.

So much of the excellence of a life of physics for realizing the ideals of development. Now, I would like to turn to the second aspect of Oppenheimer's thought; some of the excellent and humanly great physicists I came to know internationally in the early part of my research.

During the period covered by this Conference (1950-1964), it appears to me that there have been five major developments in theory. First, the rise and the fall of Yukawa's standard model; of pions and nucleons. Connected with this was the rise (and the later fall) of the S-matrix theory. The second major development was the understanding of the role of flavor symmetries, in particular, of flavor $SU(3)$. The third development concerned with emergence of chirality; the fourth, the Nambu-Goldstone spontaneous symmetry breaking phenomena; and the fifth, the Yang-Mills-Shaw gauge theory and its application to electroweak unification.

I have told the story – at least of my humble part in it – in respect of the last three developments – the rise of chiral symmetry, of spontaneous symmetry breaking and of the electroweak unification – in the Stockholm Lecture of 1979 – including the story of interactions with Pauli, Peierls, Ward, Weinberg, Glashow and others. I shall not repeat this, except to say that I can take legitimate pride in that both the Yang-Mills theory as well as the flavor eightfold way were independently invented by two of my good pupils within the ethos of my research groups at Cambridge and London.

For tonight, I shall concentrate mainly on the story of the short-lived rise of the pion-nucleon theory as the standard model of 1950-51, in consequence of the proof that this was the only theory which could be renormalized then. The people concerned with my story were P.A.M. Dirac, Nicholas Kemmer and Paul Matthews at Cambridge, besides Freeman Dyson, who was visiting Birmingham, and John Ward at Oxford.

The immediate post-war generation – our generation – was brought up to believe implicitly in the Yukawa model of the nuclear force. The only open question at that time concerned the spin of the meson and the precise form of the

nucleon-meson interaction. After Yukawa, Nicholas Kemmer – at least outside Japan – had made the most crucial contributions towards defining this problem. In a classic paper written at Imperial College, London, 1938, he had classified the Yukawa interactions – according to meson-spins and parities, and whether they were direct or derivative couplings. When I started research in October 1949, Kemmer was at Cambridge. Surprising though it may seem, I had started life as an experimental research student in the Cavendish, with a remit to scatter tritium against deuterium for Sam Devons, now Professor at Columbia. My finding myself as an experimenter was in accordance with the Cambridge tradition – handed down from Rutherford's days; those who fared well in the Physics Tripos became experimentalists; those who got third classes were consigned to theoretical research. Soon after starting, I knew the craft of experimental physics was beyond me. It was the sublime quality of patience – particularly patience with the recalcitrant equipment at the Cavendish – which I sadly lacked. Reluctantly, I turned my papers in, and started instead on quantum field theory with Nicholas Kemmer, in the exciting department of P.A.M. Dirac.

I said I started on theory research, but it was not that easy. Those were the days of renormalization theory with the papers of Tomonaga, Schwinger, Feynman and Dyson providing feverish excitement. At Cambridge, Nicholas Kemmer was the only senior person interested in these developments. He had behind him not only the kudos of having tabulated all possible meson interactions, but also the reputation of being a prince among men – of generousness to a fault to his students. So I went to Kemmer and requested him to accept me for research. He said he had eight research students already and could not take any more. He suggested I go to Birmingham to work with Peierls. But I could not bear to leave Cambridge – principally because of the beauty of the rose gardens at the Backs of my College – St. John's. (Incidentally, Dirac was at St. John's College also.) I asked Kemmer, "Would you mind if I worked with you peripherally for the time being?" He graciously assented. In my first interview with Kemmer, he said, "All theoretical problems in Quantum Electrodynamics have already been solved by Schwinger, Feynman and Dyson. Paul Matthews has applied their methods to renormalize meson theories. He is finishing his Ph.D. this year. Ask him if he has any problems left."

This was early 1950. So I went to Matthews and asked him what he was working on and if he had any crumbs left. The first piece of advice Matthews gave me was to forget the papers of Schwinger and Feynman and to concentrate on Dyson's two "classical" papers – particularly his most recent in 1949 where he had shown that quantum electrodynamics was renormalizable to all orders in α . He told me he had spent one and a half years already, trying to renormalize meson theories. He had found that only spin zero may work. He was writing up his one-loop calculation for his Ph.D. and had shown that the theory of spin zero mesons was indeed renormalizable up to the second order.

Matthews had at that time already tabulated which theories may possibly be renormalizable with the techniques then known. He had come to the conclusion

that no derivative coupling meson theory could be renormalized at all, and that among the direct coupling theories with nucleons, the only hopeful were either spin-zero, or the neutral vector theory (with massive mesons) could be renormalizable. He had also shown that the neutral vector meson theory with mass was a replica of electrodynamics and one could take over the work of Dyson more or less intact and show its renormalizability. Regarding the spin-zero theories, he had shown that one would, at the least, need an additional $\lambda\phi^4$ term where ϕ is the meson field. The corresponding term for electrodynamics ($e^4 A^4$) was gauge variant, as had been remarked on by Dyson – with John Ward actually providing that the corresponding infinity did not exist.

The ϕ^4 term for spin-zero mesons would however be a new fundamental interaction term with a new fundamental constant λ . A new fundamental constant appeared just too radical those days, and we agonized over this. But the real question was: could one be sure that even with this new interaction term, all the infinities could be assimilated to a renormalization of the meson-nucleon coupling constant, the masses of the mesons and the nucleons, plus a renormalization of their wave functions and of the new constant. Matthews had worked with one-loop diagrams and shown that renormalizability appeared possible. He could not go beyond one-loop because overlapping infinities started to come in for higher loops and one had to solve this basic problem, before progress could be made. This was the situation around March 1950.

Matthews had his Ph.D. viva shortly afterwards. His external examiner was Dyson who was visiting Birmingham at that time. Dyson used to spend a few months at Birmingham and the rest in the US. In the viva, Dyson had asked Matthews about overlapping infinities. Dyson had asked him, "Have you come across these infinities? And if so, how do you resolve the problems posed by these?" And Matthews had replied, "You have claimed in your paper on Quantum Electrodynamics (QED) that these infinities – which occur in the self-energy graphs – can be properly taken care of. I am simply following you." No further question on these infinities was asked; both Dyson and Matthews kept silent after this brief exchange.

Now overlapping infinities had indeed appeared in QED where a general self-energy graph can be viewed as an insertion of a modified vertex at either end of the lowest order self-energy graph. Insertions of modified vertices at both ends would be tantamount to double-counting. But Dyson, in his paper, while discussing these, had recommended precisely this – that one should subtract the vertex-part sub-infinities twice before subtracting the final overall self-energy infinity. Dyson must be right; but why? And what made life awkward was that whereas this troublesome overlap occurred only for self-energies in QED, for meson theories, the overlaps of the infinities were everywhere.

With characteristic generosity of which I became a life-long recipient, Matthews said to me, "My viva is over. After my degree, I'm going off, to take a few months holiday. And then I'll go to Princeton. You can have these problems

of renormalizing meson theories till I get back to work in the fall. And if you don't solve it by then, I'll take it back."

That was the sort of gentlemen's agreement we parted on. So I had to get to the bottom of the overlapping infinity problem before the fall. I thought that the best thing for me would be to ask Dyson's help. So I rang him. I said: "I am a beginning research student; I would like to talk with you. I am trying to renormalize meson theories, and there is this problem of overlapping divergence which you have solved. Could you give me some time?" He said, "I am afraid I am leaving tomorrow for the US. If you wish to talk, you must come tonight to Birmingham." So I traveled from Cambridge to Birmingham that evening. Dalitz and his gracious wife put me up for the night.

Next morning, Dyson came to the Department – this was the first time I had met him. I said, "What is your solution to the overlapping infinity problem?" Dyson said, "But, I have no solution. I only made a conjecture." For a young student who had just started on research, this was a terrible shock. Dyson was our hero. His papers were classics. For him to say that he had only made a conjecture made me feel that my support of certainty in the subject was slipping away. But he was being characteristically modest about his own work. He explained to me what the basis of his conjecture was. What he told me was enough to build on and show that he was absolutely right. I traveled with him to London that afternoon. He was due to catch his boat from Southampton later that day. I think it was during that train journey, in conversation with Dyson, that I appreciated for the first time how weak the weak forces really were.

At Cambridge, amid the summer roses at the backs of the Colleges, I went back to the overlapping infinity problem, to keep the tryst with Matthews' deadline. Using a generalization of Dyson's remarks, I was able to show that the spin-zero meson theories were indeed renormalizable to all orders. At that time transatlantic phone calls for physics research had not been invented. So I had vigorous correspondence with Dyson, with the fullest participation of Kemmer, my supervisor. Exciting days indeed!

The subtraction procedure that I designed worked in momentum space. A crucial element of the proof was to associate with a given graph a set of integration variables in momentum space such that for the entire graph or for any of the sub-graphs contained in it, every possible infinity could be associated – on a one-to-one basis – with a single sub-integration. Assuming that this was possible, the subtraction procedure left behind an absolutely convergent remainder – absolutely convergent in the mathematical sense. To prove this one-to-one relationship, one had to consider the topology of the graph. I could show, with Res Jost's help, that this result certainly holds for the so-called renormalizable theories. I have always felt very proud of this particular part of the proof (*Physical Review*, 84:426 [1951]), but to my knowledge, the paper embodying this has never been referred to by anybody ever. I can only assume that the result has been taken on trust and that no one has ever re-checked it.

Contemporaneous with mine was the work of John Ward at Oxford, who devised a most ingenious scheme of regularization. This depended on differentiation with respect to external momenta and this was the technique used later by Gell-Mann and Low in their beautiful work on the renormalization group. Later still, other regularization schemes were devised in X-space, notably by Hepp, Speer, Bogoliubov and Parasiuk. My procedure, however, was a straightforward subtraction in momentum space. And it would also permit a count of the wave function renormalization (Z) factors correctly in all conceivable situations. (P.T. Matthews and Abdus Salam, *Physical Review*, 185, [1954]). Matthews and I wrote a brief review of these developments for *The Reviews of Modern Physics* of October 1951 in which we stated the following criterion for acceptability of proof in this subject: "The difficulty ... is to find a notation which is both concise and intelligible to at least two people, of whom one may be the author." We left it unsaid that "the other person may be the co-author".

I can here tell a story about this work being considered deep and believed in, but seldom read. I was invited to the Institute for Advanced Study at Princeton in January 1951. I had by then applied my technique to renormalize charged spin-zero mesons interacting with photons. I took a manuscript copy of the new paper to Robert Oppenheimer to read and, if he approved, to send to the *Physical Review*. I then realized that I had given him a copy with no diagrams in it. So I went to his office to retrieve the manuscript. I had to wait for some while because he had visitors, but then he came out of his inner office, saw me and said, "I enjoyed reading your paper. It is a fine paper." I should have kept quiet but like a fool, I said: "I am sorry, I gave you a copy in which there were no diagrams. I don't think you could have understood it." Oppenheimer visibly changed color. But he only said, "The results are surely true and intelligible even without diagrams."

This proof of renormalizability of spin-zero meson-nucleon direct-coupling theory had come at an opportune time. With the discovery by Cecil Powell of the pion and the subsequent determination of its spin as zero, theory and experiment seemed to converge to a definitive standard model of nucleons and pseudoscalar pions, with a direct Yukawa plus the Matthews interaction. Our elation, however, was short-lived. The Yukawa coupling which nature seemed to favor was not the direct renormalizable pseudoscalar coupling but the unrenormalizable pseudo-vector coupling. The two couplings were only equivalent in the lowest order – but with the large coupling diameters $g^2/4\pi \approx 14$ – was order by order perturbation of any practical significance?

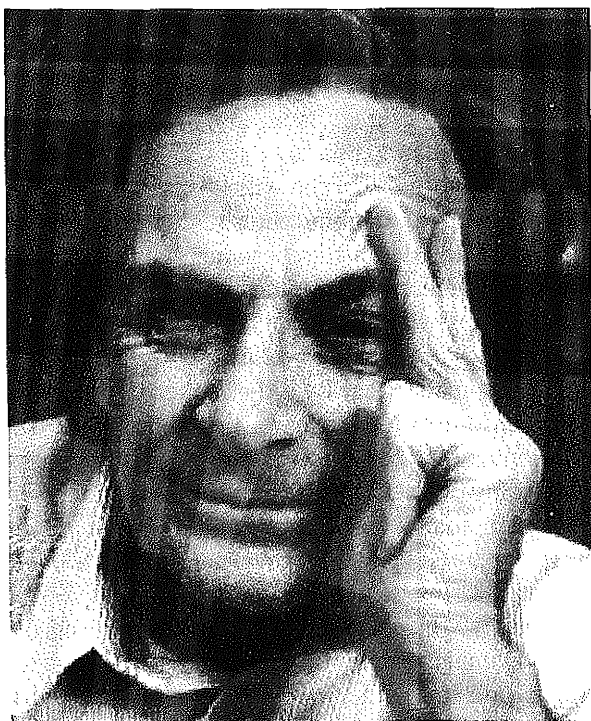
Then came the discovery of the Δ ($\frac{3}{2}, \frac{3}{2}$) resonance, plus the discovery of the form factor for the nucleon by Hofstadter. These coups de grace finally killed the model. Influential in our thinking was also the paper of Fermi and Yang, which questioned whether the pion was a fundamental entity or merely a nucleon-anti-nucleon composite.

For me personally, the disenchantment with the pion-nucleon theory had started much earlier. One of the post-war texts on nuclear physics was D. Rosenfeld's, which I believe he wrote in a wall-cellar during 1944-45 in Belgium. This was a 600-page book, which then cost £6 – the equivalent of something like \$80 today. As a research student, I had invested in the book, with great reluctance; it had burned a hole in my meager pocket. The book consisted of the theory of the deuteron, a complete analysis of meson-theoretic nuclear forces, with Moller-Rosenfeld mixtures and the like; and a description of pion-nucleon scattering phase-shifts analyses below 1 MeV. Then Hans Bethe came to lecture at the Cavendish; during this lecture he made the categorical statement that all known deuteron parameters as well as any phase shift analyses below 1 MeV, could determine no more than two parameters of the nuclear potential; the scattering length and the effective range. While listening to the lecture I kept thinking, "Surely this result Bethe has announced makes a book like that of Rosenfeld irrelevant?" The thought crossed my mind that just after the lecture finishes, everyone who has acquired a copy of the book will be trying to dispose of it. So, immediately after Bethe finished, I rushed to my lodgings at St. John's College, retrieved my copy and made a sprint to the Heffers Bookshop from which I had purchased the book. The sharks at Heffers offered me £3 if they were to buy the book back even though it was in mint condition. I accepted, but of course now I feel sorry that I sold it, because the book contained marvelous tables on harmonic functions.

I started my remarks with Dirac, who did not believe in the renormalization ideas, which we were pursuing in 1950-51. He listened to us, but always maintained the hope for a finite theory. He was recently proved right by the rise of supersymmetry theories, some of which are completely finite – among them the $N=2$ and $N=4$ supersymmetry theories and more recently by the superstring theories. In three decisive years, 1925, 1926, and 1927, with three papers, Dirac laid, first, the foundations of quantum physics as we know it; secondly, he laid the foundation of quantum theory of fields; and thirdly, that of the theory of elementary particles, with his famous equation of the electron. No man except Einstein has had such a decisive influence in such a short time on the course of physics in this century. But additionally for me, Dirac, whom I later came to know better, at the Trieste Centre, represented the highest reaches of personal integrity of any human being I have ever met. Knowing him has been one of the excellences of my life of physics.

I will conclude with a story of Dirac and Feynman that perhaps will convey to you, in Feynman's words, what we all thought of Dirac. I was a witness of it at the 1961 Solvay Conference. Those of you who have attended the old Solvay Conferences will know that at least then, one sat at long tables that were arranged as if one was sitting to pray. Like a Quaker gathering, there was no fixed Agenda; the expectation – seldom belied – was that some one would be moved to start off the discussion spontaneously.

At the 1961 Conference, I was sitting at one of these long tables next to Dirac, waiting for the session to start, when Feynman came and sat down opposite. Feynman extended his hand towards Dirac and said: "I am Feynman." It was clear from his tone that it was the first time they were meeting. Dirac extended his hand and said: "I am Dirac." There was silence, which from Feynman was rather remarkable. Then Feynman, like a schoolboy in the presence of a Master, said to Dirac: "It must have felt good to have invented that equation." And Dirac said: "But that was a long time ago." Silence again. To break this, Dirac asked Feynman: "What are you yourself working on?" Feynman said: "Meson theories" and Dirac said: "Are you trying to invent a similar equation?" Feynman said: "That would be very difficult." And Dirac, in an anxious voice said: "But one must try." At that point the conversation finished because the meeting had started. ▯



52. Richard Feynman

30

Nuclear Security, Disarmament and Development

The world's stock of nuclear weapons, which was there in 1945 has been growing ever since and is 50,000 in 1985. These numbers include "strategic" "intermediate" and "tactical" weapons. The average yield is $\frac{1}{2}$ megatons of TNT per weapon. Nearly two trillion dollars of the public funds have been spent over the years to improve their destructive power, and the means of delivering them. One indicator of the awful power of these weapons is that the explosive yield of the nuclear weapon stockpile today by the US, the USSR, the UK, France and China is equivalent to one million Hiroshima bombs. Less than 1,000 of these 50,000 weapons could destroy the USA and USSR. A thousand more in an all-out nuclear exchange could destroy the world as a habitable planet, ending life for the living and the prospects of life for those not yet born, sparing no nation, no region of the world.

Hannes Alfven has suggested that the word "annihilators" should be used for nuclear weapons, to bring home mankind their real nature. The awful point about nuclear annihilators is that the destructiveness has only superficially sunk in. We continue to think of a nuclear war in terms of the historical experience of mankind with wars in the past. "Thus, though it is recognized that the only value of nuclear weapons is deterrence, how many weapons are necessary for deterrence has never been made clear by either superpower. Can the objective of deterrence be expressed in absolute terms? Does it represent a minimum of ten city-destroying weapons or 1,000? How many lives, what proportion of the enemy's industrial capacity, have to be assured of extinction? The uncertainty of what the opponent may do next encourages the worst-case assumptions and makes the competition open-ended."

"The military strategists have gone on from the doctrine of 'deterrence' to 'damage limitation'. 'Damage limitation' meant that nuclear weapons must be given the capability to destroy other nuclear weapons before they could sow death and destruction. Thus one could justify unremitting efforts at modernization: goals of pin-point accuracy, an MX with the power to blow up missiles in their silos, the ultimate Star Wars defense through satellite system."

Speech delivered at the "Groupe de Bellerive Conference on Nuclear War, Nuclear Proliferation and Their Consequences", Geneva, June 27-29, 1985.

I should not be misunderstood; I am not criticizing one superpower versus another. I will mostly use the US figures in this article only because they are the more readily available. The truth is that both superpowers, equally, as well as all members of the nuclear club, stand indicted before the bar of humanity. A most pertinent question in this regard has been asked by the UN Secretary General in his speech to the General Assembly on December 12, 1984, voicing the thoughts of all of humanity:

"As I look across this hall, I see the delegations of 159 member nations. Almost all of the world's peoples are represented here. All of them – all of us – live under the nuclear threat. As Secretary General of this organization, with no allegiance except to the common interest, I feel the question may justifiably be put to the leading nuclear-weapon powers: by what right do they decide the fate of all humanity? From Scandinavia to Latin America, from Europe and Africa to the Far East, the destiny of every man and every woman is affected by their actions. ... The responsibility assumed by the great powers is now no longer to their populations alone: it is to every country and every people, to all of us.

"No ideological confrontation can be allowed to jeopardize the future of humanity. Nothing less is at stake: today's decisions affect not only the present, they also put at risk succeeding generations. Like supreme arbiters, with our disputes of the moment we threaten to cut off the future and extinguish the lives of the innocent millions as yet unborn. There can be no greater arrogance. At the same time, the lives of all who live before us may be rendered meaningless. For we have the power to dissolve in a conflict of hours or minutes the entire work of civilization, with all the cultural heritage of humankind. ...

"At a time of uncertainty for the young and despair for the poor and the hungry, we have truly mortgaged our future to the arms race – both nuclear and conventional. ... The arms trade impoverishes the receiver and debases the supplier. Here, there is a striking resemblance to the drug trade. Yet we continue on the same course even when faced with the silent genocide of famine that today stalks millions of our fellow men and women. The international community has to focus and act on the link between disarmament and development. We should take concrete and far-sighted steps towards the conversion of arms industries from military to civilian production. And we should begin to redress some of the enormous imbalance between research on arms and research on arms limitation and reduction. ..."

In the context of security, it is pertinent to reflect from the point of view of developing countries.

Security for us in the developing world means not only security from a nuclear winter, which may be unleashed on mankind by accident or through the

design of "homicidal maniacs", but also security from conventional wars waged on our soils. Since 1945, there have been one hundred and five wars (with deaths of 1,000 or more per year), with or without superpower involvement. These have been fought in sixty-six countries – all of them in the Third World. Twelve of these are being waged today, in more than one third of which the richer countries are implicated. "On the average, each has lasted three and a half years. They have caused sixteen million deaths, the majority of them in Asia. Cambodia lost two million, over one quarter of its population; Vietnam 2.5 million or 6% of its population; Nicaragua, by the end of 1983, had lost 1.5% of its population with 35,000 deaths; and El Salvador 45,000 deaths, with 1% death toll. Most of these deaths took place among civilians with incalculable material and social costs; for example, in Iran, where damage to the civilian economy may be over one hundred billion dollars; or in Afghanistan, – next door to my country – where daily carnage continues, with superpower involvement. "With already four out of five adults illiterate, 17,000 schools have been destroyed."³ Thus, loss of security for us in the developing world is something, which is more immediate, something we constantly live with.

Regarding the military expenditure, conventional and nuclear, reduced to numbers, "the world's arms race and its effect on human life easily loses touch with reality." The current global war-budget is around \$700 billion per year, out of a total global GNP of 12,000 billions. Of this expenditure, 550 billions is attributed to the developed and 150 billions to the developing countries.

Twenty-five million men under arms; one billion – one quarter of humanity – live under military-controlled government; and more than nine million civilians have been killed in "conventional" wars since Hiroshima.

How much are the superpowers spending on war today? "At \$855 per capita in 1982, military expenditures in the US are to be compared with \$75 in comparable prices just before World War II. The military effort has risen faster than GNP, with the US spending 6.5 percent of GNP as compared with one percent pre-war." The implications this has in respect of diminishing social expenditures need not be spelled out. Similar figures, even more stark in proportion, apply to the USSR.

"Between 1960 and 1983, the world as a whole spent some eight trillions (out of a total GNP of around 154 trillions) on military expenditures. "While military expenditures of developed countries (including the centrally-planned) rose by more than \$400 billion, the foreign economic aid rose by no more than \$25 billion in 1982; the superpower military expenditures were 17 times larger than their extension of aid to countries in need."

³From Ruth Leger Sivard's *World Military and Social Expenditures*, 1983.

And it is not just the superpowers, which have spent lavishly on war. With the rich countries' drive to sell arms, the developing world has been equally profligate. "Among the 25 countries which since 1981 have had to negotiate to reschedule their debt, six had spent more than \$1 billion each for arms imports, in the five years preceding. Between them the 25 piled up a bill of \$11 billion for arms in that period. Among 20 countries with the largest foreign debt, arms imports between 1976 and 1980 were equivalent to 20 percent of the increase in debt."

What does this military expenditure mean in terms of unmet global human needs? Again I quote from Ruth Leger Sivard:

Poverty – Two billion people live on incomes below \$500 per year.⁴ At least one person in five is trapped in absolute poverty, a state of destitution so complete that it is silent genocide.

Jobs – In the Third World, one in three who wants to work cannot find a regular job. In all countries it is the young people who are hardest hit by unemployment, in the US half of black teenagers are jobless.

Food – 450,000,000 persons – one tenth of mankind – suffer from dire hunger and malnutrition. There are an estimated 15 million deaths yearly from malnutrition and infection, conditions which are preventable and which society has both the knowledge and means to prevent. Every minute thirty children die for want of food and inexpensive vaccines and every minute the world's military budget absorbs \$1.3 million of the public funds.

Education – 120,000,000 young children of school age have no school they can go to. Educational neglect in fact begins at the earliest ages. One-third of the children between the ages of six and eleven are not in school. Over 250 million children in the world have not received even a basic education. To get a comparative estimate, the cost of a single new nuclear submarine equals the annual education budget for 160 million school-aged children in twenty-three developing countries.

I shall not go on laboring these points, but concentrate on just a set of proposals which had been made from time to time at the forum of the United Nations by the Governments of France, Mexico, Senegal, the USSR, and others, as well as by the Brandt Commission, to redress this balance. The proposals concern the creation of an International Disarmament Fund whose proceeds would be used for development tasks. It is hoped that such a fund may discourage war spending. In any case, it would ease warring humanity's guilt-feelings and its conscience. The most detailed proposal is that from France presented by its President, Mr. Giscard d'Estaing in his address to the UN General Assembly in 1978. This proposal, elaborated in a memorandum by the French Government (United Nations Document A/S – 10/AC.1/28), envisioned

⁴ Out of these 1/2 billion live on incomes below \$100 per year.

the fund as a new United Nations specialized agency, which would constitute a practical manifestation of the relationship acknowledged by the world community to exist between disarmament and development. Contributors to the fund would be those states, which were both most heavily armed and most developed; beneficiaries of the fund would be those States which were least heavily armed and least developed.

In principle, the fund would be based on the disarmament dividend approach, that is, on resources released by disarmament measures. However, the French proposal also provided for a transitional phase of the fund with an initial one-time endowment of \$1 billion, until resources derived from disarmament savings could become its long-term basis. In its transitional phase, contributions to the fund would be assessed on the basis of a State's level of armament, measured by the possession of certain types of weapon systems the existence of which according to the proposal, could be objectively determined. The fund would make grants or loans to developing countries, utilizing as much as possible existing international agencies for the administration of its loan and grants.

Various criteria could be used in the transitional stage to identify "the richest and most heavily armed" countries. Assuming that the five permanent members of the Security Council would be automatically included, the following criteria have been suggested (1977 statistics in 1977 US dollars):

As a criterion of wealth: a per capita GNP of more than \$1,000;

As criteria of armaments: a level of military expenditure in excess of 2 percent of GNP; a volume of military expenditure in excess of \$US 1.5 billion.

Of the sum foreseen as the contribution during the transition stage, amounting to \$1,000 million, 50 percent should be based on the States' nuclear armaments and 50 percent on conventional armaments. The criterion used to determine the relative contributions for the nuclear sector of the United States of America and the Union of Soviet Socialist Republics could be their number of vehicles, based on the SALT Agreement. The joint participation of these two countries would amount to 80 percent of the whole sum. China, the United Kingdom and France would jointly contribute 20 percent.

One may disagree with the details but the intention of setting up such a fund is clear and commendable. For today's discussion, I propose that we should spend our time discussing the modalities of setting up such a fund and its uses. I believe the two questions are linked. My remarks are mainly addressed to the last issue.

Why have such proposals for disarmament funds so far fallen by the wayside?⁵ Is it that such resolutions at the United Nations forum among delegates to UN bodies seldom bear fruit? If this is so, I believe that for effectiveness, we

⁵ I suppose the setting up of such a fund unilaterally by their own nations never strikes the statesmen-proponents.

must engage the young men and women – particularly in the developed countries – in the crusade of getting their governments to act. The public outcry, focused principally against nuclear weapons, is today firmly backed. How soon it will begin to affect government priorities is not yet clear but it has already become a healthy counter-weight to official policy that has lost touch with reality. It is imperative that this movement would embrace the constructive issue of development linked to nuclear and conventional disarmament.

But to effect this, we must remember that the young people today are not moved by the totality of global development tasks; nor always by dangers of unchecked population increase, nor by polarization of poverty and riches nor by world illiteracy. I believe that what immediately moves the young today are: i) the environmental problems; ii) death from hunger, and, iii) the desirability of eradication of dread diseases like leprosy and trachoma.

My feeling is that if we ask for funds for eradication of illiteracy or generally for bridging the gap between the rich and the poor or for solving the energy problems of the world – however worthy all these causes may be – it is unlikely that we shall succeed in getting enough public support. I would therefore like to argue that – at least at the outset – we should set out the goals of the Disarmament Fund to deal with: i) problems of global environment; ii) death from hunger, and, iii) eradicable human disease.

Consider global environment. The biosphere has been likened in its thinness to "dew upon an apple". Its survival intact is mankind's survival. Take one aspect of its health, connected with the preservation of rainforests situated in the Third World. According to the report presented to President Carter giving global projections for the year 2000, significant losses of world forests – particularly those in the tropics – are predicted for the next twenty years, principally as demand for fuelwood and food, both from the poor and the rich, increases. The world's forests are now disappearing at the rate of 18-20 million hectares a year (an area half the size of California), with most of the loss occurring in the humid tropical forests of Africa, Asia and South America. The projections indicate that by the year 2000 some 40 percent of the remaining forests cover in less developed countries will be gone.

I wish to emphasize that an important factor in this disappearance is man's greed. According to a recent study made by Catherine Caufield: "In the face of big business, the environment would seem to stand little chance of survival. The beef-producing industry provides a perfect example. Because Latin American beef is half the price of America's own home-produced grass-fed variety, more and more of the land is being turned into pasture – much of it at the expense of the rainforests."⁶

⁶Catherine Caufield. 1985. *The Rainforest*. London: Heinemann.

The question should be asked: Is the saving of this global heritage to be left to the poor impoverished countries of the South only? Should this not be a charge on a global fund – possibly linked with disarmament?

Why is the disappearance of the tropical forests, proceeding now at 2% of the forest per annum, disastrous for mankind as a whole? One of the many ecological reasons is the anticipated annihilation of a large fraction of species and organisms, which inhabit these forests.

"Approximately 1.5 million kinds of organisms have been named and classified, but these include only about half a million from the tropics. Many tropical organisms are very narrow in their geographical ranges and are highly specific in their ecological and related requirements. Thus, tropical organisms are unusually vulnerable to extinction through disturbance of their habitats." Since more than half of the species of tropical organisms are confined to lowland forests, in most areas, these forests will be gone within the next 20-30 years; and with them most of the three million of these organisms.

"With the loss of the organisms, we give up not only the opportunity to study them, but also the chance to utilize them to better the human condition, both in the tropics and elsewhere. The economic importance of wild species, a tiny proportion of which we actually use, has been well documented. Suffice to say that the entire basis of our civilization today rests on a few hundred species out of the millions that might have been selected, and we have just begun to explore the properties of most of the remaining ones. Unfortunately, this process of extinction cannot be reversed."

But how does a Global Development Fund come into this? In a recent issue of the *Bulletin of Atomic Scientists*, P.H. Ravan has argued that if the West cannot find the means to eliminate real poverty in the ecologically devastated areas, the people living there will topple any Government; be it friendly or unfriendly! Thus it is no coincidence that El Salvador is ecologically the most devastated of all countries of Central America and yet the authors of the Kissinger Report pay no attention to the ecological problems which force peasants to shift to and destroy permanently, through cutting of forest cover, the productivity of their marginal lands. One may in this context ask if it is not the concern of the environmental groups in the developed countries to help to preserve this global heritage? Should they not come to the rescue of the developing countries? Should this type of global assistance not be a first charge on the international communities and on a Global Development Fund?

A second area for which such a fund may be used is freedom from hunger with the Ethiopian tragedy still on public conscience. Favorable climate, water, good arable land and chemical inputs are the four factors essential for enhancing food production. According to the Carter Report the global area of arable land will increase only four percent by the year 2000, so that most of the increased output of food will have to come from higher yields. During the same period expected increases in world population are nearly in the 30-40% range – from 4.2

billion to 6 billion. Unfortunately, to feed this enhanced population, and to avoid recurrence of other Ethiopias, most of the elements which contribute to higher yields of food crops – fertilizer, pesticides, energy for irrigation, and fuel for machinery – depend on the scarce resources of oil and gas.

To make the problem more difficult, regional water shortages will become severe. In the 1980-2000 period population growth alone will cause requirements for water to double in nearly half the world. Still greater increases would be needed to improve standards of living. In many less developed countries, water supplies will become increasingly erratic by the year 2000 as a result of extensive deforestation. Development of new water supplies will become more costly virtually everywhere.

“Unless action is taken, serious deterioration of agricultural soils will occur worldwide, due to erosion, loss of organic matter, desertification, salinization, alkalization, and waterlogging. Already, an area of cropland and grassland approximately the size of the state of Maine is becoming barren wasteland each year,” and the spread of desert-like conditions is likely to accelerate. Offices of India’s Planning Commission reported recently. “We in India are on the verge of an enormous ecological disaster, with our water reserves drying up. What is happening in Africa is going to happen in India within a few decades.”

So far as the chemical inputs for enhanced agriculture are concerned, in December 1982 in the Philippines, under the auspices of the International Union of Pure and Applied Chemistry, six hundred top ranking chemists of the world met and drew up a plan of action where chemistry could be utilized to raise world food productivity through chemical inputs in fifteen years – the goal being to increase world food productivity by 50% by the year 2000. A number of world institutes for teaching, training and research for chemists from the Third World were to be created. If they are not, it will mainly be because of shortage of funds.

The World Resources Institute of Washington DC, has made a list of some of the truly serious ecological problems which are deserving of wide international attention:

i) Loss of crop and grazing lands due to desertification, erosion, conversion of land to non-farm uses, and other factors. The United Nations reports that, globally, farm and grazing land are being reduced to zero productivity at the rate of about twenty million hectares a year.

ii) Depletion of the world’s tropical forests, which is leading to loss of forest resources, serious watershed damage (erosion, flooding, and siltation), and other adverse consequences. Deforestation is projected to claim a further one hundred million hectares of tropical forests by the end of this century.

iii) Mass extinction of species, principally from the global loss of wildlife habitat and the associated loss of genetic resources. One estimate is that more than 1,000 plant and animal species become extinct a year, a rate that is expected to increase.

iv) Rapid population growth, burgeoning Third World cities and ecological refugees. World populations will most likely double by the early decades of the next century, and almost half the inhabitants of developing countries will live in cities – many of unmanageable proportions.

v) Mismanagement and shortages of fresh water resources. Water borne diseases are responsible for perhaps 80% of all illness in the world today.

vi) Overfishing, habitat destruction, and pollution in the marine environment. Twenty-five of the world's most valuable fisheries are seriously depleted today due to overfishing.

vii) Threats to human health from mismanagement of pesticides and hazardous substances and from pathogens in human wastes and aquatic vectors. An estimated 1.5 to 2.0 million persons in developing countries suffer acute pesticide poisoning annually and pesticide-related deaths are estimated at 10,000 a year.

viii) Climate changes due to the increase in "greenhouse gases" in the atmosphere. The steady build-up of carbon dioxide and other gases in the atmosphere, due principally to fossil fuel burning, is predicted to create a "greenhouse effect" of rising temperatures and local climate change – the question increasingly is not "if?" but "how much?" For a variety of reasons, poor countries are likely to suffer disproportionately from the consequence of climate change.

ix) Acid rain and, more generally, the effects of a complex mix of acids, ozone and other air pollutants on fisheries, forests, and crops.

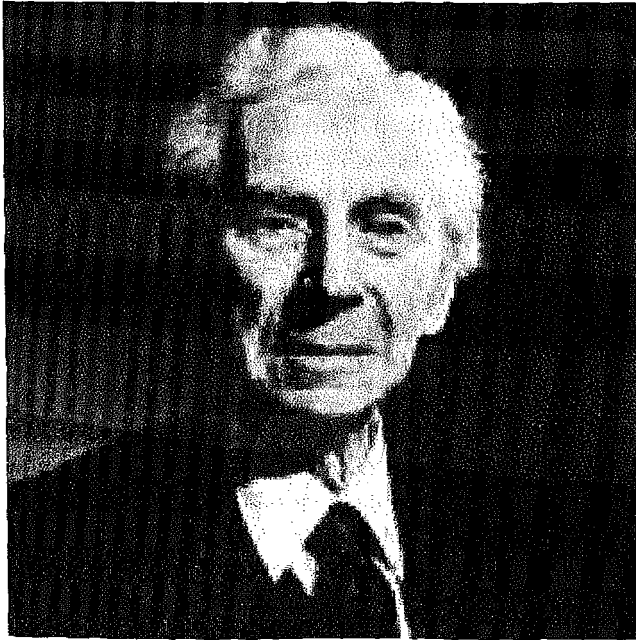
x) Mismanagement of energy fuels and pressures on energy resources, including shortages of fuelwood, the poor man's oil. Although the energy crisis is in temporary remission in the developed countries, the high costs of oil imports and fuelwood shortages continue to plague much of the developing world.

And this brings me finally to one of the most crucial charges on a Disarmament Fund – relevant scientific research in the areas of global environment, food and dread disease.

"At the cutting edge of the military competition between the major powers is a mobilization of research resources without parallel in history. The results of this research provide an irresistible momentum to the arms race. The postwar take-off in weapons research was even more spectacular than the rise in military expenditures in general. In the US, government-financed military R&D jumped from \$1.7 billion in fiscal year 1974 to \$22.1 billion in fiscal year 1983 (both in 1980 prices). The 13-fold increase in research expenditures was four times as fast as the already very rapid growth in US military spending over the same period."

The stark fact is that one half of mankind's research effort is on military R&D. The scientific talents of these men and women together with the resources devoted to military R&D might have been spent on research on ecology, climate, food and disease.

In this context, consider climate studies. I do not know whether one can really hope to change the climate; but surely it is a scandal that there is no scientific study of the climate of the Sahelian area over a long-term period. The universities in these areas have Departments of Meteorology but these Departments are weak, ill-organized and without any funds. They could be made stronger. Can one hope for a Global (Disarmament Development) Fund to organize the building up of indigenous scientific communities for carrying out such studies in the countries concerned? "The truth is that mankind is already engaged in the "Third World War" – the war against our heritage of resources – against life on Planet Earth. And we are winning it." ■



53. Bertrand Russell

31

Science and Peace

Science is the central fact of the twentieth century for Peace and War. So far as Peace is concerned, there are three aspects of Science and Peace which I shall be concerned with: 1) Peace among industrialized countries, in particular, the super powers. This aspect of the problem is concerned essentially with science and nuclear peace. 2) Peace among developing countries and between the industrialized and developing world. Willy Brandt pointed out in his Third World Prize Lecture in April this year: "The destructive machinery accumulated by the industrialized countries is actually killing people without arms being used ... The billions of dollars, that the world spends on military purposes, really amounts to a death sentence for millions of human beings." I shall argue that Brandt's remarks should be extended, not only to the billions of dollars which he has mentioned but also to the scientific talent and expertise – one half of the world's total scientific effort is concerned with military R&D. 3) A third aspect of Science and Peace is that of the individual responsibility of the scientist.

That this issue of Science and Peace is important was first brought to my cognizance by Bertrand Russell addressing a gathering of scientists. His opening remark was, "Gentlemen, do not delude yourselves. Since Archimedes prostituted his talents in the service of war for Syracuse, scientists and technologists have been using their expertise to further the war aims of tyrants and others in the name of defense of their countries." Fortunately, we in this hall are not alone in worrying about science and its relationship to peace. There are other groups which have emerged lately in all developed countries; groups like physicians for social responsibility, physicians for the prevention of nuclear war (comprising the set of people who have spoken against Nuclear Winter and who were awarded the Nobel Prize for Peace this year). Then there are groups of scientists against nuclear arms, computer professionals for social responsibility, electronics professionals for peace and computing and social responsibility. The last three groups, consisting of computer professionals, have been particularly visible lately, attempting to bring to public attention some of the technical problems with President Reagan's Strategic Defense Initiative (SDI). There are unfortunately no influential groups of scientists in developed countries who might worry about Peace and Science (or rather the lack of it) for the developing world.

Address at a meeting organized by the Independent Commission for International Humanitarian Issues, Vienna, December 16, 1985.

I said Science is the central fact of the 20th century life. There is no question but that the shape of the present world, as we see it, is the product of science and technology of the last one hundred years – in particular of the: 1) science and technology which eliminated poverty, disease and early death for the developed countries (Sweden suffered from famine one hundred and fifty years ago); 2) of the technology of communications and telecommunications which have made the concept of One-World come true; 3) of the technology, for example, behind the penicillin revolution, responsible for the recent population explosion; and 4) of the technologies behind modern food production, of chemicals, pesticides and insecticides which have kept this population alive.

Some of these are positive aspects of science. On the negative side are the aspects of science and particularly the technology connected with modern weapons of destruction, that have led to the attitude of suspicion which the present generation has acquired against science and technology. To be specific, physics has brought mankind near to atomic annihilation. Chemistry – or the misuse of chemistry – has wrecked the environment, while medicine and biology, in spite of all their triumphs in eradicating diseases of the rich, have not addressed themselves to the problems of diseases of the poor in developing countries where many a dread disease – malaria, trypanosomiasis, bilharzia – still await remedies. An example of what medical science could achieve if properly harnessed is provided by the eradication of smallpox, accomplished by the action of the World Health Organisation (WHO) recently. Why other diseases cannot be similarly eradicated is clearly due to lack of funds and lack of research on these diseases. [...]

Responsibility of Scientists in Respect of Nuclear War

In addressing this problem I shall make a distinction between science and technology, between high level scientists and the misuse of their work. Even if we keep to such a distinction, the question arises, how much responsibility does the individual high level scientist carry, for example, in respect of nuclear weaponry?

Let us briefly consider the case of Einstein, one of the most morally motivated scientists of all times, and, of course, one of the most highly valued in the sciences. Now Einstein was the father of the formula $E=mc^2$ which is at the heart of conversion of nuclear matter into destructive energy. So, in that very distinct sense, without his contribution, no nuclear bomb would have been possible. He was also the author of the first letter to Roosevelt which apparently started the Manhattan Project but then he refused to join the project itself and he initiated the Pugwash Movement after the war.

The most thorough discussion of the responsibility of the scientist is to be found in the autobiographical book of Werner Heisenberg *Physics and Beyond: Encounters and Conversations*. Heisenberg describes the time when he and his colleagues, Otto Han, Max von Laue, Walther Gerlach, Carl Friedrich von

Weizsacker and Karl Wirtz, from the atomic group assembled by the German Government, were incarcerated at Farm Hall on the edge of Godmanchester, twenty-five miles from the University of Cambridge, after the end of hostilities. On the afternoon of August 6, 1945, they heard the special news flash: an atom bomb had been dropped over Hiroshima. Heisenberg says: "At first I refused to believe it, for I was convinced that the construction of atom bombs involved enormous technical efforts and probably the expenditure of many thousands of millions of dollars. ... Worst hit of all by the news was Otto Hahn. Uranium fission, his most important scientific discovery had been the crucial step on the road toward atomic power. And this step had now led to the horrible destruction of a large city and its population, of a host of unarmed and mostly innocent people. Hahn withdrew to his room, visibly shaken and deeply disturbed, and all of us were afraid that he might do himself some injury."

Heisenberg goes on to describe his and von Weizsacker's debate on whether Hahn bore any guilt. Von Weizsacker said, "We must probably make a clear distinction between the discoverer and the inventor. ... Hahn's fission experiments were a discovery, the manufacture of the atom bomb an invention. The physicists who built the bomb in America were inventors; they were not acting on their own behalves, but on the overt or implicit orders of a warring group anxious to obtain the maximum striking power for its army."

Heisenberg countered this by saying, "perhaps US physicists were afraid that Germany might be the first to produce atom bombs. And understandably so. ... I don't think any of us could really object to that, particularly if we consider what happened in our concentration camps. ... We should not criticize them, for who among us was able to prevent any of the revolting crimes our Nazi government has committed? The fact that we did not know the full extent of these crimes is no excuse, for we ought to have made greater efforts to find out."

Von Weizsacker's reply was, "If we believe that, then we ... blame American physicists for not having tried hard enough to make their voices heard in public and for leaving to others the decision to use the atom bomb long before they had to do so. For I have no doubt at all that the evil consequences of dropping the bomb must have been quite obvious to them from the start." Heisenberg said in response, "I don't know whether the word 'blame' is appropriate in this context. I simply feel that in this particular respect we happened to be luckier than our friends across the Atlantic."

Heisenberg goes on in later parts of his book to speak of his own disputes with Chancellor Adenauer. Adenauer had declared in public, "that the acquisition of atomic weapons was nothing more nor less than a strengthening of our artillery, and that there was only a difference of degree between nuclear bombs and conventional arms." According to Heisenberg, "this was nothing short of deception and we felt compelled to do something about it and make our view public. ... We believed that we could lend weight to our declaration if we, as individuals, solemnly refused every form of participation in any atomic

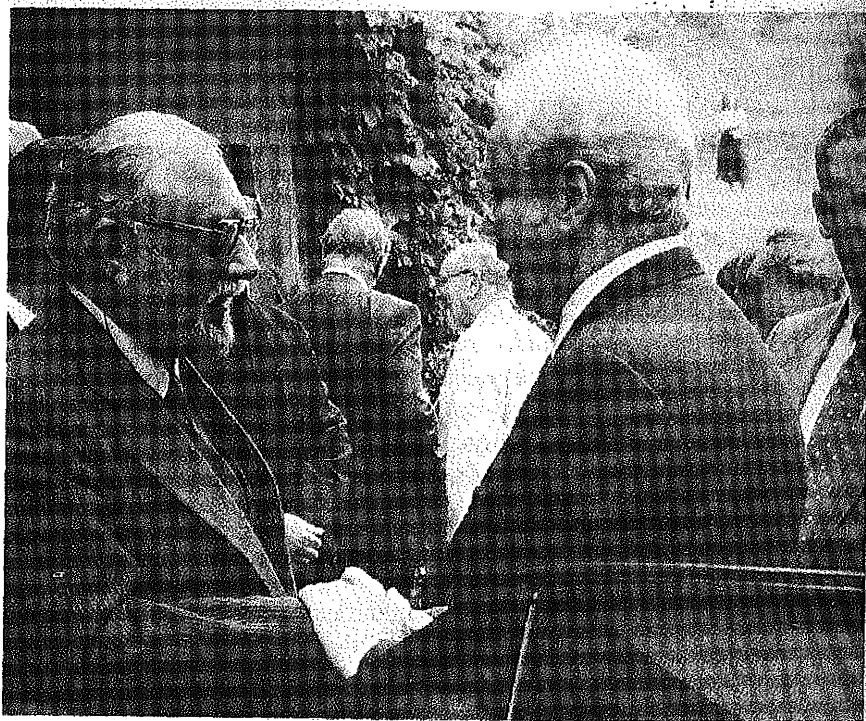
rearmament programme." This was the basis of a declaration which was published on April 16, 1957 and "obviously had a strong effect on the German public. ... Adenauer was upset by a campaign that ran counter to the course he had carefully chosen, and he invited several of the physicists for a discussion in Bonn." Heisenberg refused because he "could not imagine that any fresh or helpful ideas would emerge."

All honor to Heisenberg. But does this resolve the issue of whether scientists should organize an oath like the oath of Hippocrates which medical men take, on not to work on scientific projects – including projects in biotechnology and bioengineering – which could eventually be detrimental to humankind. This issue is very much to the fore of US and UK campuses in respect of the Strategic Defence Initiative (SDI). Unfortunately, so far as the spread of nuclear weapons is concerned in the conditions of today, or even for the success of a partial SDI program, such action will not be decisive since it is not the high-level scientist who is needed any more, in the production of nuclear weapons or SDI systems, it is rather the technologist who can exploit the principles of science already discovered and in many instances clearly used for peaceful purposes. Whether such men would take such an oath any more than professional soldiers, or munition-makers, depends on factors and the society's priorities which go beyond the question of a scientist's responsibilities.

Let me conclude by telling you of a recent initiative which we have taken in Trieste, that is, the setting up of the Third World Academy of Sciences. This academy brings together eminent men of science from Third World countries who will be concerned, not only with the health of science in our countries, but also with the global South projects for research in these matters. The first meeting of the Academy was addressed by the Secretary General of the UN on 5th of July this year and brought together delegates from sixty-three countries, both developing and developed, to discuss the question of research for peace, prosperity and health of mankind. The Secretary General in his eloquent address said: "All honor to science which explores the universe and solves its mysteries. All honor to it as it examines the constitution of life. All honor to it as it elucidates the working of the mind-body organism. All honor to it as it seeks to alleviate pain. All honor to it as it enlarges the providence of the earth and all honor to it as it ensures better communications between human beings and societies – but no honor to science which has no compassion and is heedless of man's hope and man's fear: the fear particularly in our age of the whole human species committing suicide."

Nine hundred years ago, a great physician of Islam, Al-Asuli, living in Bukhara, wrote a medical pharmacopoeia which he divided into two parts: "Diseases of the Rich" and "Diseases of the Poor". If Al-Asuli were alive and writing today about the afflictions wrought upon itself by mankind, I am sure he

would divide his pharmacopoeia into the same two parts. One part of his book would speak of the affliction of nuclear annihilation inflicted on humanity by its richer half. The second part of this book would speak of the affliction which poor humanity suffers from – underdevelopment, undernourishment and famine. He would add that both these diseases spring from a common cause – excess of science and technology for the case of the rich, and lack of science and technology for the case of the poor. He might also add that the persistence of the second affliction of mankind – underdevelopment – was hard to understand, considering that the world has enough resources, technical, scientific, and material to eradicate poverty, disease and early death for the whole of mankind, *if it wishes to do so.* ■



54. Salam welcoming UN Secretary-General Javier Perez de Cuellar for inauguration of the Third World Academy of Sciences (TWAS), July 5, 1985

32

Drought, Desertification and
Food Deficit Study-Project

It is a privilege and pleasure to send a message on behalf of the Third World Academy of Sciences to this august international gathering, comprising representatives of the Organization of African Unity, the host Government, members of the African Academy of Sciences, the National Academy of Sciences, the McArthur Foundation, the World Bank, the US Board on Science and Technology for International Development, and the representatives of the Italian Ministry for Foreign Affairs.

My remarks will be principally addressed to the subject of the study-project on Drought, Desertification and Food Deficit in Africa, at whose inception we have gathered. This project concerns not only the Sudano-Sahelian zone south of the Sahara, but also a number of countries in Southern Africa. It is a fresh study of the ways in which science and technology may be purposefully used for ameliorating the starkness of distress and for enhancing the welfare of Africa – this, by engaging international scientific expertise as well as the continent's own scientific capacity in the study.

There are a number of remarkable things about this project which need to be emphasized.

First, the Drought, Desertification and Food Deficit problem is a highly complex one, comprising physical and biological as well as the human dimensions. It must, therefore, be approached in a multidisciplinary manner, harnessing the best international scientific talent for the study.

Second, in order to be successful, the program of action which will be proposed should consist of short-range as well as of long-term elements.

Third, in this study, the involvement of African scientists is crucial. This is in respect of the utilization of already existing, excellent studies and reports, which still await implementation and support. In these studies, emphasis was placed, by and large, on providing outside assistance. In contrast, the drought, desertification and food deficit team of international and African scientists' plans to emphasize, from the outset, the building up of local capabilities and the development of local scientific leadership and institutional management.

Presented at the Symposium on Utilization of Indigenous Scientists in National Development, Nairobi, Kenya, June 1-6, 1986.

I think I can do no better than describe how the idea of this particular project started. I hope you can bear with me while I tell the story, for it has several morals for our present project. In April 1985, the Third World Foundation (located in London) organized a meeting in New York at the United Nations in order to discuss nuclear issues and their impact on the development of the poorer countries. There I met Prof. Jerome Wiesner, ex-Provost of MIT.

Now, in 1961, Wiesner and I had both been concerned with a scientific project involving my country, Pakistan. The Pakistan project had its beginning at the centennial celebrations held at MIT under the chairmanship of Wiesner. It was at this meeting, that Prof. P.M.S. Blackett, Nobel Laureate in Physics, of Imperial College, London, made his famous speech when he said that all the science which developing countries needed for their development had already been discovered; they had no further to go except to buy in the world supermarket of science and technology.

I was the next speaker after Blackett. I humbly disagreed with my august professor. As an illustration, I spoke of the blight of water-logging and salinity in Pakistan which had destroyed the fertility of twenty-three million acres of land in our country, and for which there seemed no cure.

When I finished speaking, Wiesner came to me and said, "I have just been appointed Science Adviser to Kennedy. Can you come with me to Washington? Let's plan a scientific team to look into this problem." So we did. Roger Revelle, who had been Head of the Oceanographic Institute at La Jolla, and who was then the Science Adviser to the Secretary of the Interior – with an office next to Wiesner's in the White House Annex, was induced by Wiesner to assemble a team of twenty to thirty scientists, from research institutions and universities, to go out to Pakistan. This was January 1961. By July 1961, when President Ayub Khan made a State Visit to the US, President Kennedy was able to make an official offer for sending Roger Revelle and his team to Pakistan to investigate scientifically the problem of water-logging and salinity afresh.

What was so special about this team? First, it consisted of non-commercially committed men of science, with a fresh outlook. Second, they were members of a multi-disciplinary team. Third, there was an involvement of the two governments – the US and Pakistan – so that the hope was that the recommendations of the team would find active support, so far as implementation was concerned.

The rest is history and Roger Revelle can tell it better than I can. His team toured Pakistan. They came to the conclusion that we in Pakistan had been pursuing the right course – pumping out saline water from the affected lands into new drainage canals, except that – and this was the crucial new point which they made – we were pumping over too small parcels of land – 50,000 acres only. We must pump *simultaneously* over one million acres so that a net outflow could be

established after leakage from the neighboring areas was taken into account – the well-known maximization of area over circumference Effect in Operational Research.

With Pakistan's scientists' involvement, this remedial measure has now worked for the last twenty-five years: Pakistan is a surplus country so far as food is concerned. As I said, there are a number of morals in this story. First, a fresh approach by uncommitted scientists may uncover a newer slant to the solution of an old problem; second, one must have local scientific involvement; third, after the study stage, there is the stage of implementation for which the highest governmental involvement may be needed.

Now, in New York last year, when we met, Wiesner and I agonized about the Sahel situation, and the need for a similar multidisciplinary scientific approach to it, involving both the international scientific expertise as well as the local African Community. Could one perhaps mount a similar team to explore the Sahel, and at the same time, build up African science and African institutes in this context?

That same night, Wiesner acting on behalf of the McArthur Foundation, called up Roger Revelle. On the other side, the US National Academy of Sciences and the African Scientists – led by Tom Odhiambo – who had come together for the first meeting of the Third World Academy of Sciences at Trieste in July 1985, decided to collaborate together. We also succeeded in having the interest of the World Bank, through its Vice Presidents, Mr. Moeen Qureshi and Mr. S. Shahid Husain, and of the Italian Government – in particular of the Under Secretary Mr. Forte – and of Bostid.

This, briefly, is the genesis of this project, so far as we in the Third World Academy are concerned. What shape it will take in the future is for this meeting to determine.

Some of the scientific aspects of the problem which need examination are clear and have been spelt out by Revelle and Odhiambo. These concern: 1) Plant nutrient chemistry of African soils; 2) Irrigation with both ground and surface water; 3) Afforestation and agroforestry practices; 4) Reduction of soil erosion and the development of farming systems; 5) Insect control, particularly of the Tse-tse fly.

Other relevant factors concern: a) Control of trypanosomiasis; b) control of river blindness; c) why the green revolution has been so relatively unsuccessful in Africa; d) the possibility of setting up 'cattle camps'.

Odhiambo has also rightly stressed that in addition to the short term plan – involving the scientific mission led by Revelle – we need a medium term plan of vigorous training for young African scientists, plus a long term plan of scientific institution building in Africa. Who will play the role of President Kennedy and President Ayub Khan for this project is yet unclear, but on behalf of the Third World Academy of Sciences, we can pledge all our humble help. May Allah bless your efforts. ■

33

Highlights of Science for Turkey

It is an honor and a privilege for me to have been invited to speak on Physics in the Year 2000 in Turkey and in the Islamic World, at this gathering convened by the prestigious journal, the *Insan ve Kainat*, and in the presence of those who run this great country.

My experience of dealing with the development-related Sciences derives from directing and running a United Nations International Centre for high-level physics research located in Trieste, since 1964. Since its inception, this Centre has had the privilege of welcoming of the order of 29,200 experimental and theoretical physicists, more than half of them working in research institutes and universities in developing countries. I am also privileged to be responsible for the Third World Academy of Sciences, which comprises prestigious scientists from our countries and as such a purview of the year 2000 in sciences falls under the Academy's mandate. Professor Feza Gursey whom you all know is one of the distinguished Fellows who graces this Academy.

Now first and foremost one must realize that Turkey represents a great nation, which has contributed from the earliest times to Islamic scholarship and science. The recently published *Encyclopedia of Islamic Science*, edited by Saban Dogen, is a witness to the preponderance of Turkish names among those who created science in Islam.

Today Turkey has a population level nearly that of Great Britain and France and some five times larger than that of Sweden. There is no reason why Turkey should not be a leader of sciences, certainly by the year 2025, if the right priorities are allocated to science. So far as physics is concerned, during the last fifteen years, the Centre at Trieste alone has been privileged to welcome four hundred and thirty-four visits of physicists from Turkey, such is the enthusiasm of Turks for this subject. In this context, it is wise to remember that physics is an incredibly rich discipline: it not only provides us with the basic understanding of the Laws of Nature, it also is the basis of most of modern high technology. Thus physics is the "science of wealth creation" par excellence. This situation may well change in the 21st century, but this is true today. This is even in contrast to chemistry and biology, which together provide the "survival basis" of food

— Speech at the Symposium on "Turkey in the Year 2000", Istanbul, November 5-7, 1986.

production as well as of pharmaceutical expertise. Physics takes over at the next level of sophistication. If a nation wants to become wealthy, it must acquire a high degree of expertise in physics, both pure and applied. The Third World as a whole is slowly waking up to the realization that – in the last analysis – science and technology distinguish the South from the North. On science and technology depend the standards of living of a nation and its defense standing. The widening gap between nations of the North and the South is basically the science gap. To see this gap, just turn over the pages of a multidisciplinary science journal – like *Nature*. Not more than 1% of the papers originate in the South, and if any occasional Southern names are among other contributions, these are either Ph.D. students or Southern researchers who have migrated to the North.

Now, while the South is making some purposeful efforts to acquire technology, very few of us have yet woken up to the need of acquiring science as well. I shall therefore spend the bulk of my time speaking of science transfer.

Let me begin by calling to your minds the year 1799 in Turkey: Against the opposition of the 'Ulema – and surprisingly even a section of the military establishment – in that year Sultan Selim III did introduce the subjects of algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey. He imported French and Swedish teachers for teaching these disciplines. His purpose was to rival European advances in gun-founding. Since there was no corresponding emphasis on research in these subjects, and particularly, in materials research, Turkey could not keep up with the newer advances being made elsewhere. The result was predictable: Turkey did not succeed. Then, as now, technology, unsupported by science, will not flourish.

As my second example, take the situation in Egypt at the time of Muhammad Ali, thirty years after the episode with Selim III that I have just recounted. Muhammad Ali in Egypt had his men trained in the arts of surveying and prospecting for coal and gold in Egypt. This attempt was unsuccessful but it did not strike him, nor his successors, to train Egyptians on a long-term basis in the sciences of geology or of related environmental sciences. Thus, till this day, there is not one high-level Desertification Research Institute in the entire sub-continent of North Africa or the Middle East (except in Israel). When we recently organized a course on the Physics and Mathematics of the desertification process, we had to import teachers from Denmark – with their experience on the wastes of Greenland!

My third example is again from Egypt, where, I am told, three million dollars were spent in setting up a factory for the manufacture of thermionic valves. The factory was built in the same year that transistors were perfected and began to invade the world markets. The recommendation to set up the thermionic valve factory was, of course, naturally made by foreign consultants. It was, however, accepted by Egyptian officials who were not particularly perceptive of the way science was advancing, and who presumably never consulted the competent physicists in their own country.

Why do we neglect science and technology based on science so far as development is concerned? First and foremost, there is the question of national ambition. Let me say it unambiguously. Countries of the size of Turkey, or Egypt, or my own country, Pakistan, have no science communities geared to development because we do not want such communities. We suffer from a lack of ambition towards acquiring science, a feeling of inferiority towards it bordering sometimes even on hostility.

In respect of ambition, let me illustrate what I mean by the example of Japan at the end of the last century, when the new Meiji constitution was promulgated. The Meiji Emperor took five oaths. One of these set out a national policy towards science – "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness and security of Japan." And what comprised "knowledge"? Listen to the Japanese physicist, Hantaro Nagaoka, specializing in magnetism – a discipline to which the Japanese have contributed importantly, both experimentally and theoretically since. Writing in 1888 from Glasgow – where he had been sent by the Imperial Government – to his Professor Tanakadate, he expressed himself thus: "We must work actively with an open eye, keen sense, and ready understanding, indefatigably and not a moment stopping. There is no reason why the Europeans should be so supreme in everything. As you say, we shall beat those *yattya bottya* (pompous) people (in science) in the course of ten to twenty years."

The same happened in the Soviet Union sixty years ago when the Soviet Academy of Sciences, founded by Peter the Great, was asked to expand its numbers and was set the ambition of excelling in all sciences. Today it numbers a self-governing community of a quarter of a million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. According to Academician Malcev, this principally came about in 1945, at a time when Soviet economy lay shattered by the war. Stalin decided at that time to increase emphasis on sciences. Without consulting anyone else, he apparently decided to increase the emoluments of all scientists and technicians connected with the Soviet Academy, by a factor of three hundred percent. He wanted bright young men and bright young women to enter massively the profession of scientific research, and he succeeded.

Among the developing countries today, from experience at Trieste, we can perceive just five which do value science and science-based technology, whatever else be their hang-ups. These countries are Argentina and Brazil in Latin America, and China, India and South Korea in Asia. Barring these five, the Third World, despite its realization that science and technology are the sustenance, and its major hope for economic betterment, has taken to science as only a marginal activity. This is, unfortunately, also true of the aid-giving agencies of the richer countries and also the agencies of the United Nations.

Assuming that you agree with me that science has a role for development, why am I insistent that science in developing countries has been treated as a marginal activity? Two reasons:

First: Policy makers, prestigious commissions (even the Brandt Commission), as well as aid-givers, speak uniformly of problems of technology transfer to the developing countries as if that is all that is involved. It is hard to believe but true that the word "science" does not figure in the Brandt Commission report. Very few within the developing world appear to stress that for long term effectiveness, technology transfer must always be accompanied by science transfer, that the science of today is the technology of tomorrow and that when we speak of science it must be broad-based in order to be effective for application. I would even go so far as to say; if one was being Machiavellian, one might discern sinister motives among those who try to sell to us the idea of technology transfer without science transfer. There is nothing which has hurt us in the Third World more than the recent slogan in richer countries of "Relevant Science". Regretfully, this slogan was parroted in our countries unthinkingly to justify stifling the growth of all science.

Second: Science transfer is effected by and to communities of scientists. Such communities need building up to a critical size in their human resources and infrastructure. This building up calls for wise science policies with four cardinal ingredients – long-term commitment, generous patronage, self-governance of the scientific community, and free international contacts. Turkey, as I am told, has a total of 7,000 non-clinical Ph.Ds. Of these around 1,000 are basic scientists – 400 being physicists working in the universities and research organizations. On US, Japanese, or European norms, the numbers of physicists should be ~4,000, a factor of 10 larger. But this is not the whole problem. The real problem is that, in our countries, the high-level scientist has not been allowed to play a role in nation building as an equal partner to the professional planner, the economist and the technologist and this has gone on so long that the scientist has even forgotten that he should be claiming a stake towards development. Few developing countries have promulgated such policies for science; few aid agencies have taken it as their mandate to encourage and help with the building up of the scientific infrastructure, with a view to the scientists' deployment in development, and few scientists can or do fight for their community's share of such tasks.

Why science transfer? What is the infrastructure of sciences I am speaking about, and why? First and foremost, we need scientific literacy and science teaching at all levels, and particularly at the higher levels – at least for the sake of the engineers and technologists. This calls for inspiring teachers, and no one can be an inspiring teacher of science unless he has experienced and created at least some modicum of living science during some part of his career. This calls for well-equipped teaching laboratories and (in the present era of fast moving

science) the provision of the newest journals and books. This is the minimum of scientific infrastructure any country of any size must provide for.

Next should come demands on their own scientific communities from the developing country's government agencies and their nascent industries, for discriminatory advice regarding which technologies should be acquired.

Still next, for a minority of the developing countries, there is the need for indigenous scientists to help with their applied colleagues' research work. For any society, the problems of its agriculture, of its local pests and diseases, of its local materials base, must be solved locally. One needs an underpinning from a first-class base in sciences to carry through applied research in these areas. The craft of applied science in a developing country is made harder, simply because one does not have available next door, or at the other end of the telephone line, men who can tell you what one needs to know of the basic principles relevant to one's applied work.

I spoke earlier of indifference towards science. When I was recently consulting my Turkish colleagues, I was told that this came sometimes even from the engineering community – a community which, in Turkey, enjoys reputation and status. I was surprised by this, for many reasons. Firstly, in Pakistan, my experience is that a lack of appreciation of the possible role of scientists stems from the shortsightedness of planners and economists and not engineers. (The same remark was made to me incidentally by Brazilian scientists.) Secondly, I was surprised because in the history of recent fundamental advances of Physics, a crucial role has been played by engineers. Thus, for example, Y. Nishina, the man who first brought high-level physics to Japan and who was the teacher of the two Japanese Nobel Laureates in Physics, H. Yukawa and S. Tomonaga, was an electrical engineer by profession. P.A.M. Dirac, the creator of quantum mechanics who, in my opinion, is the greatest figure in physics of the 20th century, was trained as an electrical engineer. Eugene Wigner, who won a Nobel Prize for Physics, started life as a chemical engineer.

To reinforce my remarks, let me recall that in 1961, I attended the centennial celebrations of the founding of the Massachusetts Institute of Technology, perhaps the most important technological school of the United States. To my surprise, it was the engineers at this school who wanted the modicum of science to be increased in their curricula.

The remarks I have just made are a repetition of what I had the privilege to say at the UNDP meeting held here on September 2, 1985 in Istanbul. In my speech at that time, I mentioned that Greece had joined the Centre for Nuclear Research at Geneva, the largest and the most prestigious European organization for Particle Physics Research, with an annual budget of a quarter of a million dollars. Greece displayed the ambition of joining the big league in science and one can visibly see as a result the maturity which Greek Physics has acquired and its transformation year after year. How this maturity will reflect itself in the area of development, will, of course, depend on the policies which Greece will pursue in employing these men. But the physicists will be there, at any rate.

I am very glad that my voice did not go unheeded and that Turkey is proposing to join the European Organization for Nuclear Research (CERN) like Greece has already done, at least as an associate member. If properly used, this could be a source of high technology besides high science, particularly as CERN has wisely decided to grant a 10-year remission to a payment of the full quantum of membership dues (a few million dollars) for new applicants like Portugal, Spain and Turkey. In the first year of joining, 9/10 of these funds will be spent on building up technical infrastructure – computers, data analysis, microprocessors, detection-device technology, vacuum science and technology – *within* Turkey. The following year this share will be 8/10's, the following year 7/10's within Turkey and so on. As I said, if it is wisely planned, Turkey could build up High Science as well as High Technology through this enforced spending within Turkey.

While I am speaking of high technology, I am assuming, of course, that Turkey is going to follow the same pattern for its development as a country equal to it in size, so far as population is concerned. This is South Korea. South Korea had the advantage over Turkey of 100% literacy – as against 52%¹ – when it started on this forward course fifteen years ago. As you are aware, South Korea has increased its GNP from \$100 per capita to \$2,000 over this period. They had access to a number of Koreans trained in the United States. Turkey has a similar advantage today of having had a part of its working population trained in the technologies of metallurgy, automobile fabrication and the like, in Germany and other European countries. Just now, South Korea has embarked on a new phase of wishing to develop its basic sciences, in addition to excelling in fiber optics, microchip manufacture, and microprocessors, so much so that when I visited that country six weeks ago, I was asked to appear in a television interview lasting two and a half hours, together with Korean physicists. They told me that South Korea had made it a national objective to win Nobel Prizes and they wanted me to give advice to young people on how to achieve this. Such an objective may seem rather strange to some people, but not to the South Koreans.

The second area, which may be exploited by the year 2000 is the area of Photon Physics. In its weekly section on Science and Technology, the *London Economist* three weeks ago (October 18, 1986), writing under the caption "The Future Belongs to the Photon", had this to say:

One factor which may have affected literacy in our countries is the authorities' and the Mullahs' opposition to printing. Though Turkey was the first among Islamic countries to authorize printing – as early as 1727 – when Ibrahim Muteferrika received authorization through an imperial edict to publish the first edition of a 1583 manuscript on the "newly discovered Americas" – Ibrahim Muteferrika's presses were stopped at his death, and printing did not resume in Turkey till the middle of the nineteenth century. The authorization to print the Holy Book (but in Arabic text only) was granted only in 1874 – a full three hundred and twenty years after the Gutenberg's Bible!

Electronics has been the main engine of innovations since the invention of the transistor 40 years ago. Most of tomorrow's interesting technologies will work by manipulating light, not electricity. The electronics revolution is not young. The electron was identified less than a century ago and the microchip, on which today's information-technology industry utterly depends, has been around for fewer than 20 years. The successes crammed into these two hectic decades have created the impression that electronics is a technology capable of limitless improvement.

It is not. Electronics will give way to a superior technology based not on electricity but on light. Physicists did not realize until early this century that light came in the separate packets they now call photons. But science has made startling progress in manipulating photons. A photonics revolution is already in the making.

Why is the switch (to photons) worth making? Because photons travel faster than electrons; because they have no mass; because (unlike electrons, which interfere with each other) photons can be made to pass through each other unperturbed. ...

Moreover, electronics is discovering its limits. Electronics has not reached that limit yet, but it is drawing close enough to worry engineers.

The customary way to make computers cheaper and faster is to squeeze electronic components closer together. The number that can be fitted on a single chip has grown from about a dozen twenty years ago to two million today. But miniaturization, too, is bumping against limits. When components get too close, the chips are plagued by 'cross-talk' – the leakage of charges from one component to another. ...

The case for a photonic solution is compelling. Sending several electric currents through one chip at the same time risks cross-talk and disaster. Not so with beams of light: a chip could process several at once without their interfering with each other. ... Consider how rapidly light has nudged electronics out of two pillars of information technology: telecommunications and the storage of information.

In communication, telephone companies are tearing out their copper cables as quickly as they can afford to and replacing them with hair-thin optical fibres made of glass. Light is a better messenger than electricity.

One way or another, light looks like the wave of the future.

This is an area where the future is just beginning. A nation can join at the ground floor. As I was told in Japan, companies like Fujitsu and Sony and Hitachi do not rely on their superb technologists alone to excel. It is their Ph.Ds in Physics, etc. – men who know photons (and electrons) intimately – who are responsible in the last analysis for adding innovative quality to their products. Turkish craftsmen have demonstrated their predilection for miniaturization technology – writing whole suras of the Holy Qur'an on a grain of rice. Could they not excel equally in the newly emerging field of photon physics?

The third area I wish to stress for the year 2000 for Turkey is Biotechnology. I wish to stress this since, partly on account of my urging, the Italian Government has accepted, together with the UNIDO organization, to create in Trieste an international center on Biotechnology for developing countries, like mine for Physics.

As is well-known, the modern advances in genetics started with the unraveling of the genetic code by Watson and Crick. This great discovery in biology – one of the most synthesizing discoveries of the 20th century, possibly of all time – was made at Cambridge in April 1953 by two contemporaries of mine, one American, the other British, working at the world-famous Cavendish Laboratory which specializes in basic physics. [...]

Biotechnology is one of the newer sciences. Like physics today, biotechnology's applications are expected to dominate the 21st century – in agriculture, in energy, in medicine. My next excerpt describes the obstacle which the developing world (including the World of Islam) faces in building up expertise in this subject. This is a quote from a guest editorial from the journal *Biotechnology*. "Biotechnology thrives on new knowledge generated by molecular biology, genetics and microbiology, but these disciplines are weak, often nonexistent, in the underdeveloped world. Biotechnology springs from universities and other research institutions, centers that generate the basic knowledge needed to solve practical problems posed by society. But the universities of the underdeveloped world are not research centers. And the few creative research groups operate in a social vacuum; their results might be useful abroad, but are not locally. Biotechnology needs dynamic interactions among the relevant industries. These interactions, however, are weak in countries in which science is perceived as an ornament, not as a necessity. Biotechnology requires many highly skilled professionals, but underdeveloped nations lack sufficient people well trained in the pertinent disciplines. Economic scarcity and political discrimination induces professionals and graduate students to emigrate or abandon science altogether."

The writer goes on to ask "What can be done?" and his answer is: "First of all, underdeveloped countries must understand that they need to reform their universities. They must recognize that molecular biology is not just another branch of biology, but the one and only tool available for understanding biological structure and function. Success in biotechnology depends on the conquest and consolidation of the moving frontiers of cell biology and medicine."

I am sure India, China, Argentina, Brazil and South Korea, among the developing countries, will take heed of this call. The question is, shall Turkey and the Muslim nations take heed also or shall we lose out in this new race to master and utilize biotechnology?

Let me summarize. We must ensure that we do not lose out in new Physics, nor in Physics-based High Technology, nor in Biotechnology. That is if we wish to live honorably in the 21st century; and wish to defend our culture and our civilization. We must ensure that our scientific enterprise is of first-class quality in these disciplines (like the South Koreans have ensured), and that it maintains living contact with international science. After all, science is at present being

created – and at a furious pace² – outside the confines of our countries. At present, very few of us, if living and working in our own countries, can travel to scientific institutions and meetings abroad. Such travel, as a rule, is considered a wasteful luxury. In some of our countries, incredibly, it needs authorization from the highest authority in the land!

So far as biotechnology is concerned, as I said, the Italian local community at Trieste, in consonance with the government in Rome, has donated funds to found an international institute of biotechnology. The local funds from the Government of the Trieste Region are of the order of forty million dollars. Many other client countries will benefit – Turkey also. But I cannot understand why Turkey – the Region of Istanbul – should not found an international institute of biotechnology at the same level with its own manpower, which, if planned properly, can be built up in a short time.

For physics, I know from my personal experience of working with them, that Turkish physicists are some of the most imaginative. They undertake difficult problems in physics consciously – and this is something I respect. I had the privilege of visiting this great country a short while back when I was honored to be received by President Kanan Evren. I suggested to him that, in my opinion, what Turkey needed in its national priorities and plans was something analogous to the Bell Telephone Laboratories in the United States in the field of physics of communications. The Bell Laboratories have produced six Nobel Laureates who have contributed to basic physics, besides including transistors in their roster of inventions. I estimate that the Turkish (or the Egyptian or the Pakistani) analogue to the Bell Laboratories for Communication Physics would cost forty million dollars to build and around four million dollars yearly, to run. I believe it can be done with the highest level of quality, and that one can find those who could create it in Turkey.

In the context of a State's duties towards science, permit me, before I conclude, to present to you the Proclamation 5461 of April 17, 1986 of the President of the United States of America. This proclamation reads:

Since the time of its beginnings in Egypt and Mesopotamia some 5000 years ago, progress in mathematical understanding has been a key ingredient of progress in science, commerce, and the arts. We have made astounding strides since, from the theorems of Pythagoras to the set theory of Georg Cantor. In the era of the computer, more than ever before, mathematical knowledge and reasoning are essential to our increasingly technological world.

Despite the increasing importance of mathematics to the progress of our economy and society, enrolment in mathematics programs has been declining at all levels of the American educational system. Yet the application of mathematics is

² To stress this furious pace, let me recall that last week at Trieste, during his inaugural lecture on the frontier subject of Brain Research, the speaker started with the remark: "The last ten years have seen more accumulation of knowledge (and more books being made obsolete) in brain research than in the entire history of mankind."

indispensable in such diverse fields as medicine, computer sciences, space exploration, the skilled trades, business, defense, and government. To help encourage the study and utilization of mathematics, it is appropriate that all Americans be reminded of the importance of this basic branch of science to our daily lives.

The Congress, by Senate Joint Resolution 261, has designated the week of April 14 through April 20, 1986 as "National Mathematics Awareness Week" and authorized and requested the President to issue a proclamation in observance of this event.

Now, therefore, I, Ronald Reagan, President of the United States of America, do hereby proclaim the week of April 14 through April 20 1986, as National Mathematics Awareness Week, and I urge all Americans to participate in appropriate ceremonies and activities that demonstrate the importance of mathematics and mathematical education in the United States. In witness whereof, I have hereunto set my hand this seventeenth day of April, in the year of our Lord nineteen hundred and eighty-six, and of the independence of the United States of America the two hundred and tenth.

Here is an example for our nations and our rulers to emulate, of what it means to be aware of basic sciences and their importance. [...]

I was asked recently by the Education Minister of Kuwait to write on the "Future of Science in Islam" for the Islamic Summit Conference, which is going to be held in Kuwait on January 26, 1987. Among other recommendations, in this paper I have also pleaded for the creation of foundations of science and prizes of science. These foundations and prizes should come from both Islamic Governments and private donations. I have asked the question why 1/8 of the Auqaf Funds in our countries should not be devoted to sciences, in keeping with the emphasis on sciences in the Holy Book of Islam. Let us make no mistake about it; in contrast to 250 verses which are legislative, some 750 verses of the Holy Qur'an (almost one-eighth of it) exhort the believers "to study Nature, to reflect, to make the best use of reason and to make the scientific enterprise an integral part of the community's life". I have been asking Muslim divines in India and Pakistan if they were devoting one out of every eight of their Friday sermons to stressing these aspects of sciences. In reply, they said that they would have liked to, but they do not know enough science themselves. Has the time not come for them to learn and to speak of the fundamental forces of Nature and their unification, of the structure of the earth, of the fascination and magic of the genetic code as marvels revealed by contemporary science, and to bring these to the consciousness of the believers, as the Holy Book enjoins us to do?

Let me reiterate; I miss an attitude towards science so conspicuously absent from our countries from the 15th century onwards – which considers science as being an integral part of our lives. May I through you, Mr. Prime Minister, suggest that the moment has come when our courts of State should be adorned again with scientists? I am reminded of the court of King Arthur of legendary

fame; at that Court there was a Court Magician; his name was Merlin. It was his function to use magic for forging steel for swords and to provide magical medicinal potions. We the scientists are the Merlins of today. We can perform feats of magic undreamt of by Merlins of yesteryears. We can indeed transform society. But in our Third World countries, the Merlins have no place in the courts of State. Should they not be invited back? Some will say – and perhaps rightly – that the Merlins in developing countries are amateurs, they do not know their applied craft. They choose to live in their own ivory towers, and our societies are thereby forced to import the real Merlins from the West. This may be true, but why is it so? Could this emasculation have come about through the fact that our Merlins are so few in numbers, and even these few have never been permitted to make a contribution to development of their own countries. Not even by their colleagues – the economists – who in this metaphor are the High Priests of State. Only experience can teach the Merlin-Scientist the craft of developmental problem solving, even if he knew his science. This vicious cycle of lack of mutual trust must be broken, I hope, before the year 2000. From all the portents I can see – including the holding of this Conference – the year 2000 will be a glorious year of distinction in Sciences and their purposeful application towards the problems of this great land of Turkey. Inshallah. ¶

34

The Ultimate Nuclear Accident

We are assembled today to consider nuclear accidents of civilian reactors and the dispositions which mankind should make in case such accidents happen in the future. Of the past accidents, two are specifically remembered: the Three Mile Island accident in 1979 and the Chernobyl accident in 1986. According to Dr. Hans Blix, Director General of IAEA, the Chernobyl accident claimed thirty-one lives – the largest fraction, twenty-nine, from radiation exposure – with two hundred and three persons hospitalized for serious radiation poisoning, with an expectation of 5,000 to 20,000 additional cancer cases in the Soviet Union over the next seventy years, and a similar number of possible cancer deaths in Western Europe. These numbers are insignificant compared with the six hundred million cancer deaths expected in the same period. A total of 135,000 persons had to be evacuated within eighteen miles of the plant – but only temporarily. They have almost all returned by now.

When we speak of these accidents and their relative mildness – even compared to the Bhopal Chemical Plant disaster – we forget that the estimated energy equivalent of the Chernobyl explosion was only of the order of 1/10th of a kiloton. Compare this to the “Little Boy” atomic bomb dropped on Hiroshima, which had the explosive energy equivalent of fifteen kilotons of TNT, and which killed or maimed 200,000 persons; while the present stock-pile of the world’s nuclear weapons is of the order of sixteen million kilotons. In other words, the devastation which could be caused by the world’s stock pile of nuclear weapons, could be equivalent to one hundred and sixty millions of Chernobyl-like incidents. Even without taking into account the direct deaths due to fire and blast – 70,000 killed in a flash in the case of the Hiroshima 15-kiloton nuclear bomb, to be scaled up by a factor of a million – and extrapolating only from the twenty-nine radiation deaths which Chernobyl claimed, nearly two-third of the population of the five billion humans on the face of our globe could be wiped out by the present stock of nuclear weapons, if deployed in the Chernobyl mode.

Presented at the meeting at the Academy of the Kingdom of Morocco, Paris, France, June 10-11, 1987.

As is well known, the number of nuclear weapons is now over 50,000 – on the average of 1/3 megaton TNT each – of which less than 1,000, if deployed appropriately, are known to suffice to destroy each of the USA and the USSR. And one thousand more of these in an indiscriminate nuclear exchange are likely to destroy the earth as a habitable planet – sparing no nation, nor any region of the world, because of a possible onset of a nuclear winter. Such is the overkill of today's nuclear arsenals.

I shall speak of a nuclear exchange happening accidentally and onset of nuclear winter which may descend upon this planet, extinguishing human life just as the dinosaurs were extinguished sixty-five million years ago. Thus, to speak of nuclear reactor accidents today and not of the nuclear weapon accidents, is like the situation of a man falling from the 100th storey of a tall building. During his fall, he descends to the 70th floor and he says to himself: nothing is so far happening to me. Then he passes the 30th floor, and he feels even more secure, though a little weary and shaken by now. This is precisely the type of security which human beings have come to feel at the moment in spite of Three Mile Island and Chernobyl.

My thesis is that like the two accidents of the nuclear plants, which have been blamed on human operators who tampered with the engineering safety devices built into their reactors, the human element, particularly in the form of psychological stresses on those operating the nuclear weapons, could accidentally bring the world to a nuclear catastrophe.

I am encouraged to speak thus by an article recently published by the London's *Sunday Times* magazine, which gave a graphic description of life inside a nuclear submarine. These submarines can carry some 6,500 strategic warheads. According to the *SIPRI Handbook* for 1986, there are sixty-two Soviet nuclear submarines and perhaps one hundred on the Western side, in the world's oceans, each one of them capable of destroying cities, the size of Paris or Moscow, or Saint Paulo, or Calcutta. Collectively, the firing from these submarines could certainly unleash the nuclear winter I shall speak about.

In the *Sunday Times* article, we were shown the inside of one such submarine: the highly cramped space, one man on top of another; the claustrophobia; and the pressures which these men are subjected to during their long, cheerless and lightless missions at the bottom of the world's oceans.

Many of us also have seen a fictional movie which was made some while ago – *Dr. Strangelove*, and how he came to love the nuclear bomb – the insidious madness which grew over those who were dealing with these lethal weapons.

During a routine visit, a party of us a score of years ago were shown around one of the military installations, with an opportunity to speak to some of the young men who were due to fly nuclear armed bombers later. These young men had been incarcerated and segregated from their families, they were not allowed to listen to any news broadcasts and they lived in isolation for one week in advance of their mission which consisted of flying the armed bombers, subject to the fearful psychological pressures, exactly like in the film of Dr. Strangelove. Things may have eased for these crews in the intervening years, but not for the submarine crews.

My recollections of the visit include coming across one of the most devastating understatement of my life: a long cylinder was being hauled out to be loaded onto a bomber. I asked the Colonel in charge what the cylinder contained. He said airily, "It is a hydrogen bomb in the megaton range." There was some red lettering painted on the cylinder. I peered at it with curiosity. Drawing nearer, I saw that this red lettering said absolutely blandly: "Explosive". It was not even "High Explosive"!

What worries me is that in spite of the hot-line and the fail-safe devices, there is, according to the *Sunday Times* article, a residual permission given to the commanders of these nuclear submarines to fire their lethal charges in the event that they suspect something and do not receive any response from their Headquarters.

This reminds me of the accidents at Three Mile Island and Chernobyl, which in the words of Valery Legosof, the chief Soviet delegate to the IAEA meeting at Vienna, held for a post-mortem of Chernobyl – occurred because of the poor training given to the human operators. "The accident has dramatized the need for more intensive nuclear training of the plant workers. ... The accident happened because of the human weaknesses of those operating the reactor: these operators overloaded the safety systems." I hope and pray that humankind can be sure that every one involved with nuclear weapon deployment is free of all stresses and well-trained. I hope and pray that this aspect of human operators and their fallibility is not treated as cavalierly as the question of operators at the Three Mile Island and the Chernobyl was, through the false security bred by twenty-five years of accident-free operation.

Supposing though, through an accident, such a nuclear exchange as I have been talking about was initiated and did take place. Would the world end in ice or fire? Both – for so many of the nuclear scientists believe. The fear is that a nuclear exchange could throw enough dust and soot into the atmosphere to blot out the sunlight that sustains life. This theory is now four years old and a part of the nuclear nightmare.

In the words of the correspondent to the *London Economist*, the theory emerged "serendipitously". In 1971, Dr. Carl Sagan and a group of fellow astronomers became intrigued by a thick dust storm on Mars. They noticed that during the storm, the Martian atmosphere became abnormally hot, while at the same time, the surface of the planet became abnormally cool. The shroud of dust was being heated by the sun, but it reduced the amount of sunlight reaching the surface.

"Several years later, the Nobel Laureate, Dr. Luis Alvarez and his son, Dr. Walter Alvarez, began to develop a theory that blamed the extinction of the dinosaurs sixty-five million or so year ago on a shroud of dust thrown into the atmosphere when an asteroid hit the Earth." It began to dawn on Carl Sagan and his collaborators that the dust hurled into the atmosphere by nuclear explosions could have similar, or perhaps more severe, consequences. To the dust would be added sooty smoke produced by burning cities and forests.

"The hard part of the nuclear-winter hypothesis is not supplying the proof that the climate would be changed, but predicting, by how much. That the aftermath of a catastrophic nuclear accident would be inclement weather is certain." But a nuclear winter which lasts so long that it could snuff out all plant and animal life everywhere is something which could be disputed.

In 1983, Dr. Sagan and his collaborators predicted that a large-scale nuclear war would choke out the sun over the entire northern hemisphere. Temperatures would fall by 30°C, and would not return to normal for months or years. By then, the damage to plants and microbes could be irreversible.

Some scientists have disputed this because one cannot reliably predict: 1) *The amount of smoke*. Fires spread unpredictably, and how much combustible material will catch fire can only be guessed at. "Cities contain mountains of inflammables (wood, tar, asphalt, rubber, plastics, solvents, oil and gas). The amount of smoke produced by a nuclear war is put at anything from 20 million to 650 million tons. The exact numbers are critical: the amount of light absorbed by the smoke would drop off rapidly as the size of the smoke-ball falls below 40 million tons." 2) *Where the smoke goes*. "Beyond four kilometers up in the atmosphere there is little moisture and therefore little chance of smoke particles being washed out by rain. We do not know how high the smoke will be carried by the nuclear fireballs." 3) *The weather*. "Rain is hard to predict. If a large volume of water vapor is blasted up with the bomb clouds, rainfall would probably increase, washing the atmosphere clean." Dr. Edward Teller has noted that the oceans could retain their temperatures for a long time even if the land cooled off. The top few meters of the ocean have the same heat capacity as the atmosphere and as surface waters cooled they could be heated up by deeper waters. The sharp temperature differences that would be created between land

and sea would set off storms, rinsing out the smoke and may eventually return the climate to normal! 4) *Where the bombs go off*. Different assumptions about targets produce different results. That is one reason why estimates for non-urban fires made by America's defense department and by Dr. Sagan differ.

I have enumerated the objections to the extreme nuclear winter hypothesis. On the other side, one may note that one important detail neglected by Carl Sagan and his collaborators was the effect of coal dust. "Many American and Russian missile ranges are located on coal-bearing strata. Large enough ground bursts in terrain of this kind could carry tens of thousands of tons of dust directly into the stratosphere in the rising fireballs." Thus, nuclear winter could after all be even worse than predicted by Dr. Sagan!

It may be that the issue of a nuclear winter is in doubt – only some two or three billions out of a total of five plus billion humans may die in case of such an ultimate nuclear accident, while life for the remainder may continue. But what life for the survivors, with scant and contaminated food, no medical facilities, no communications, no civilization as we know it! In this context, a most pertinent question has been asked by the United Nations Secretary General in his speech to the General Assembly on December 12, 1984, voicing the thoughts of all of humanity and I shall conclude with this:

As I look across this hall, I see the delegations of 159 member nations. Almost all the world's peoples are represented here. And all of them – all of us – live under the nuclear threat. As Secretary General of this organization, with no allegiance except to the common interest, I feel the question may justifiably be put to the leading nuclear-weapon powers: by what right do they decide the fate of all humanity? From Scandinavia to Latin America, from Europe and Africa to the Far East, the destiny of every man and every woman is affected by their actions. ... The responsibility assumed by the great powers is now no longer to their populations alone: it is to every country and every people, to all of us.

No ideological confrontation can be allowed to jeopardize the future of humanity. Nothing less is at stake: today's decisions affect not only the present, they also put at risk succeeding generations. Like supreme arbiters, with our disputes of the moment we threaten to cut off the future and extinguish the lives of the innocent millions as yet unborn. There can be no greater arrogance. At the same time, the lives of all who lived before us may be rendered meaningless. For we have the power to dissolve in a conflict of hours or minutes the entire work of civilization, with all the cultural heritage of humankind. ...

At a time of uncertainty for the young and despair for the poor and the hungry, we have truly mortgaged our future to the arms race – both nuclear and conventional ... (which) impoverishes the receiver and debases the supplier. Here then is a striking resemblance to the drugs trade. Yet we

continue on the same course even when faced with the silent genocide of famine that today stalks millions of our fellow men and women. The international community has to focus and to act on the link between disarmament and development. We should take concrete and far-sighted steps towards the conversion of arms industries from military to civilian production. And we should begin to redress some of the enormous imbalance between research on arms and research on arms limitation and reduction. ■

35

A "Silent Genocide"

Our planet is inhabited by two distinct types of human beings. According to the United Nations Development Program (UNDP) count of 1983, one quarter of mankind, some 1,100 million people, are "developed". They inhabit two-fifths of the land area of the Earth, while 3,600 million "developing" humans – *Les Misérables* – live in the remaining three-fifths. I shall call them the rich and the poor respectively, although some of those in the developing world are not exactly poor in pure economic terms. It is not just the level of poverty, which distinguishes one type from the other, it is also a question of ambition and dynamism, and the differing contribution made by each type to "present day culture" and to science and technology.

During 1983, the rich countries enjoyed a total Gross National Product (GNP) of \$10.5 trillion, \$9,500 per year and per capita, or around \$800 per month. For the same year, the poor countries had a total GNP of \$2.6 trillion, an average of \$60 per capita per month. The part of the world I come from – South Asia – which consists of Afghanistan, Bangladesh, India, Nepal, Pakistan, and Sri Lanka and has a population of 1,000 million had a GNP of \$250 per capita. This means on an average \$20 a month or 70 cents a day. These 70 cents are supposed to provide us with two daily meals, clothing, shelter, health care and education, if any.

The rich quarter of humanity "lead" the "North-Centric" world of today through their economic superiority and their military prowess. They include the two superpowers, the USA and the USSR, with populations of 235 and 272 million (and GNPs of \$3.3 trillion and \$1.85 trillion, respectively). The "leaders" as a whole suffer from two problems: a nuclear psychosis and unemployment. They seem to have consciously chosen to keep 10 percent of their active population unemployed – feeding and clothing them at subsistence level.

The remaining three-quarters of humanity include some of the people who built up the oldest civilizations of the planet – the Chinese, the Hindu, the Buddhist and the Islamic. Their basic problems are lack of food (some countries are wracked by recurring famines); of shelter; of clothing; of health care; of education. Their situation is aggravated by the problems of unemployment;

adverse terms of trade; chronic indebtedness (to the tune of \$1 trillion); overcrowding; and lack of security.

I am not referring to the obviously shelterless, the obviously needy. I have in mind, rather, the uncomplaining hungry millions, who – and I speak from experience – seldom get two regular meals a day; the millions who must often choose between buying badly needed food or a schoolbook for their children. They live in a crushing poverty of the kind that has not been known in Europe and the United States since the time of Dickens. I never cease to be amazed that despite this “silent genocide”, the human spirit does not break and that most of the needy are still able to keep up a dignified appearance.

Lack of security is today one of the most unsettling aspects of life in the developing world. The causes include: military dictatorships (perhaps, as one dictator succeeds another, the struggle for sheer survival extinguishes the democratic spirit); the unsettled borders of nation-states, which are mainly a legacy of imperialism; religious fanaticism, fanned by past events; greed for territory; superpower rivalries and the insistent arms sales by the rich to the poor; apartheid.

Unfortunately, there are few points of contact between the two types of human beings. Some of these are historical in nature, a consequence of the Imperial past. Others include a shared environment – most of the tropical forests, which are the “lungs” of our planet happen to be located within the developing countries. The rich countries are just beginning to appreciate the biological importance of tropical forests for all humanity and the need to share responsibility for their upkeep. Another point of contact is the need for raw materials, substitutes for which cannot be easily found, such as oil and gas, as well as food items such as bananas.

Trade could have been an area for contact, but it is not. All the developing countries together account for no more than 20 percent of world trade. A recent study points out that “the thirty-six countries – the ‘Real South’ – with a per capita income of less than \$400 and half of the world’s population (including China, India and Pakistan) surprisingly account for no more than 3 percent of the world trade.”³

For all practical purposes, the “Real Poor”, like Frantz Fanon’s⁴ oppressed Blacks, make no mark on the present world. Like all poor anywhere; they could disappear from the face of the Earth without leaving any trace. What can be done about their predicament?

There are two contrasting answers to this question. Either to eliminate all the poor on the lines of what the Irish satirist Jonathan Swift suggests in his famous

³ Gerald Segal. *Guide to the World Today* (1987).

⁴ West Indian psychoanalyst and social philosopher known for his writings on behalf of the national liberation of colonial peoples in such works as *Black Skin, White Masks* (1967), and *The Wretched of the Earth* (1965).

"modest proposal" to solve the problem of famine in Ireland two centuries ago.⁵ Or if the conscience of the world will not accept a "final solution" (and fortunately there are people in rich countries who would oppose this), then the only other alternative is to try to restore some measure of human dignity to this assortment of peoples.

My thesis is that the situation of the developing world can be improved in the long term only through an assisted and massive importation of modern science and technology, the possession of which is the basic difference between the North and the South. Such a step may incidentally also solve the unemployment problem of the rich countries through the demand for goods and services it would generate. ▯

⁵In his *Modest Proposal for preventing the children of the poor people from being a burden to their parents or country, and for making them beneficial to the publick* (1729), Jonathan Swift suggested that economic conditions might be alleviated by using the children of the poor parents as food for the rich.

36

Scientific Thinking between the Secularization and the Transcendent: An Islamic Viewpoint

Introduction

I would like to begin by offering my profound appreciation to the Giovanni Agnelli Foundation for contributing \$3,000 to the Fund for Physics. This is a Fund, which I created for the developing countries' scientists, from the proceeds of the Prize, which was given to me in 1979. The Holy Prophet of Islam taught us to "thank men and women whenever they do good for you", for "whosoever does not thank people, does not thank Allah". In keeping with this teaching, I express my gratitude to the Giovanni Agnelli Foundation. Since the Fund for Physics represents a charitable purpose, I unashamedly say that I would appreciate it if others could join in keeping the Fund alive.

I have divided my remarks today into three parts. First, I wish to consider an issue raised by my esteemed colleagues – some of whom are Nobel Laureates – who have opined that "Science is the creation of the Western, democratic, Judeo-Christian tradition." I disagree with them and I shall explain why. Secondly, I would like to reflect – in the context of the three Abrahamic religions (Judaism, Christianity, Islam) – on the topic, which we have been asked to speak on, i.e., Scientific Thinking (as a bridge) between Secularization and the Transcendent. (I shall not speak about the high traditions of the three non-Abrahamic world creeds – Hinduism, Buddhism and Confucianism. This is simply because of ignorance. Thirdly, I shall speak on the question – why am I a believer? In this context, let me say right away that I am both a believer as well as a practicing Muslim. I am a Muslim as well as a scientist because I believe in the *spiritual* message of the Holy Qur'an. A.J. Arberry, who was Professor of Arabic at the University of Cambridge, and whose translation of the Holy Book is probably the most poetical, had this to say: "The Qur'an was the prime inspiration of a religious movement which gave rise to a civilization of wide extent, vast power and profound vitality. The literature and fine arts of all Muslim peoples spring from this fountainhead. No man seeking to live in the same world as Islam can afford to regard lightly, or to judge ignorantly, the book that is called the Qur'an. It is among the greatest monuments of mankind."

Talk at the conference organized by the Giovanni Agnelli Foundation, Turin, Italy, June 21-23, 1988.

*Part I**Openness and Democracy Within the Scientific Community*

First, I want to take up the rise of modern science and its relation to the Western democratic tradition. Clearly, the Western tradition cannot be the whole story, since this, for example, would exclude the rise of excellent science created in Japan in the present century. My own view has always been that science is the shared creation and joint heritage of all mankind and that as long as a society encourages it, science will continue to flourish within that society.

I am sure it is painful for some of you to hear, and painful for me to say, but the truth of the matter is that excellence in sciences is dependent on the freedom and openness within the scientific community in any society (assuming that such a community is large enough) and not necessarily upon the openness or democracy within the society at large. In sciences, if there is a considerable body of persons who appreciate what one is engaged in; if there is a body of persons who are permitted to discuss freely and openly their doubts, express their reservations of each other's work as well as speak out their own visions; if there is a body of persons who can discard the beliefs they cherished, if empirical evidence goes against these beliefs – then science at the highest level will continue to be created among such people. In the USSR, for example, there is a fairly large community consisting of a quarter of a million scientists who work for the Academy of Sciences and similar institutions, and who have their own reward systems and value judgments. Thus till such time as openness and scientific democracy continues to prevail among this community, science in the USSR shall flourish. Of course, it will flourish even more if the whole society accepts democracy as Mr. Gorbachev would like it to.

Second is the question of whether modern Science and Technology is a cultural phenomenon. I am prompted to ask this question because recently, my illustrious colleague, Professor Ilya Prigogine, posed this question about China: In spite of the well-known Chinese pre-eminence in technology till the 15th-16th century and their numerous discoveries of science application, why did modern science not emerge from China? He goes on to say that among the many reasons put forward is the "absence of a sovereign, law-giving God, a concept deeply entrenched in European thought at the end of the Middle Ages. What today we call classical science was born in a culture dominated by the notion of an alliance between man, situated at the interface between the divine order and the natural order, and a law-giving, apprehensible god, a sovereign architect conceived in our own image."

According to Prigogine, "the correspondence between the German mathematician and philosopher, Gottfried Leibniz, and the English philosopher, Samuel Clarke, acting as Isaac Newton's mouthpiece, is very revealing in this respect. The correspondence followed a criticism made by Leibniz in which he accused Newton of having a very poor opinion of God, since, according to

Newton, his handiwork was less perfect than that of a good clockmaker. Newton had, in fact, spoken of the constant intervention of God, the creator of a world whose activity he unceasingly nourished. In reply, Newton and Clarke accused Leibniz of reducing God to the status of a *Deus otiosus*, an idler king, who, after a once-and-for-all act of creation, retires from the stage. In classical science, dominated by the notion of the possibility of an omniscient power indifferent to the passage of time, Leibniz' view prevailed."

This is an interesting thought. If this is true, then, in all justice, there ought to be a recognition of the Islamic, in addition to the Greco-Judeo-Christian, legacy. Since this is an important point for the scientific future of one quarter of humankind, to which I belong spiritually and culturally, I shall take time to explain why I believe this to be the case in the next few sections of this paper.

The Holy Qur'an and Science

Let me affirm once again that so far as a Muslim is concerned, the Qur'an speaks to him directly and emphasizes for him the necessity for reflection on the Laws of Nature, with examples drawn from Cosmology, Physics and Biology.

"Can they not look up to the clouds, how they are created;
And to the Heaven how it is upraised;
And the mountains how they are rooted,
And to the earth how it is outspread?" (*Al-Qur'an*, 88:17)

And again,

"Verily in the creation of the Heavens and of the Earth,
And in the alternation of the night and of the day,
Are there signs for men of understanding." (*Al-Qur'an*, 3:189-190)

Seven hundred and fifty verses of the Qur'an (almost one eighth of the Book) exhort believers "to study Nature, to reflect, to make the best use of the reason in their search for the ultimate and to make the acquiring of knowledge and scientific comprehension part of the community's life." The Holy Prophet of Islam (Peace be on him) emphasized that the "quest for knowledge (and sciences) is obligatory upon every Muslim, man and woman."

Classical Science, A Greco-Islamic Legacy?

How seriously did the early Muslims take these injunctions in the Holy Qur'an and of the Holy Prophet?

Barely a hundred years after the Prophet's death, the Muslims had made it their task to master the then-known sciences. Founding institutes of advanced study (Bait-ul-Hikmas), they acquired an ascendancy in the sciences and technology that lasted up to around 1450 AD when Constantinople fell to the technologically superior Turkish cannonade.

The Golden Age of Science in Islam was doubtless the Age around the year 1000 AD, the Age of Ibn Sina (Avicenna), the last of the medievalists, and of his contemporaries, the first of the moderns, Ibn-al-Haitham and Al-Biruni.

Ibn-al-Haitham (Al-Hazen, 965-1039 AD) was one of the greatest physicists of all time. He made experimental contributions of the highest order in optics. He enunciated that a ray of light, in passing through a medium, takes the path which is easier and quicker." In this, he was anticipating Fermat's Principle of Least Time by many centuries. He enunciated the law of inertia – later, and independently – to become part of Galileo's and Newton's laws of motion. He was the first man to conceive of the Aswan Dam though he was unable to build it because the technology of the time could not keep up with his ideas. (He had to feign madness in order to escape the wrath of the Fatimid Caliph, Al-Hakim of Egypt, for having proposed the idea of the dam and not actually building it.)

Al-Biruni (973-1048 AD), Ibn Sina's second illustrious contemporary, worked in today's Afghanistan. He was an empirical scientist like Ibn-al-Haitham; as modern, as unmedieval in outlook as Galileo, six centuries later. However, it is commonly alleged that Islamic Science was a derived science; that Muslim scientists followed the ("un-Islamic") Greek theoretical tradition blindly.

This statement is false. Listen to this assessment of Aristotle by Al-Biruni: "The trouble with most people is their extravagance in respect of Aristotle's opinions; they believe that there is no possibility of mistakes in his views, though they know that he was only theorizing to the best of his capacity." Or Al-Biruni on mediaeval superstition: "People say that on the 6th [January] there is an hour during which all salt water of the earth gets sweet. Since all the qualities occurring in the water depend exclusively upon the nature of soil ... these qualities are of a stable nature. Therefore this statement is entirely unfounded. Continual and leisurely experimentation will show to anyone the futility of this assertion." And finally, Al-Biruni on geology, with this insistence on observation: "But if you see the soil of India with your own eyes and meditate on its nature, if you consider the rounded stones found in the earth however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current; stones that are of smaller size at a greater distance from the mountains and where the streams flow more slowly; stones that appear pulverized in the shape of sand where the streams begin to stagnate near their mouths and near the sea – if you consider all this you can scarcely help thinking that India was once a sea, which by degrees has been filled up by the alluvium of the streams."

In Briffault's words: "The Greeks systematized, generalized and theorized, but the patient ways of detailed and prolonged observation and experimental inquiry were altogether alien to the Greek temperament. What we call science arose as a result of new methods of experiment, observation, and measurement, which were introduced into Europe by the Arabs. (Modern) science is the most momentous contribution of the Islamic civilization."

These thoughts are echoed by George Sarton, the great historian of science: "The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due to the Muslims down to the 12th century." Clearly, it is not enough to call Modern Science, with its insistence on experiment and observation, a Grecian legacy. If anything, it is truly a Greco-Judeo-Christian-Islamic legacy. [...]

Part II

Reflections on Transcendence and Secularization

Science as Anti-religion

It is generally stated that science is anti-religion and that science and religion battle against each other for the minds of men. Is this correct?⁶

Now if there is one hallmark of true science, if there is one perception that scientific knowledge heightens, it is the spirit of wonder; the deeper that one goes, the more profound one's insight, the more is one's sense of wonder increased. This sentiment was expressed in eloquent verse by Faiz Ahmad Faiz:

Moved by the mystery it evokes,

many a time have I dissected the heart of the smallest particle.

But the eye of wonder,

its wonder-sense is never assuaged!

In this context, Einstein, the most famous scientist of our century, has written: "The most beautiful experience we can have is of the mysterious. It is the fundamental emotion, which stands at the cradle of true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed. It was the experience of mystery – even if mixed with fear – that engendered religion. A knowledge of the existence of something we cannot penetrate, our perceptions of the profoundest reason and the most radiant beauty, which only in their most primitive forms are accessible to our minds – it is this knowledge and this emotion that constitute true religiosity; in this sense, and in this alone, I am a deeply religious man." Einstein was born into an Abrahamic faith; in his own view, he was deeply religious.

Now this sense of wonder leads most scientists to a Superior Being – *der Alte*, the Old One, as Einstein affectionately called the Deity – a Superior Intelligence, the Lord of all Creation and Natural Law. But then the differences start, and let us discuss these.

The Abrahamic religions claim to provide a meaning to the mystery of life and death. These religions speak of a Lord who not only created, 1) Natural Law and the Universe in His Glory, His own Holiness and His Majesty; but also created us, the human beings in His own image, endowing us not only with speech, but also with spiritual life and spiritual longings. This is one aspect of

⁶ One must recognize at the outset that religion is one of the strongest urges of mankind, which can make men and women sacrifice their all, including their lives, for its sake.

transcendence. 2) The second aspect is of the Lord who answers prayers when one turns to Him in distress. 3) The third is of the Lord who, in the eyes of the Mystic and the Sufi, personifies eternal beauty and is to be adored for this. These transcendent aspects of religion as a rule lead to a heightening of one's obligation towards living beings. 4) The fourth is of the Lord who endows some humans – the prophets and His chosen saints – with divinely inspired knowledge through revelation.

Regarding what may (in the present context) be called the "societal", "secularist" thinking, Abrahamic religions speak of: 1) the Lord who is also the Guardian of the Moral Law – the precept which states that "Like one does, one shall be done by"; 2) the Lord who gives a meaning to the history of mankind – the rise and fall of nations for disobedience to His commandments; 3) the Lord who specifies what should be human belief as well as ideal human conduct of affairs;⁷ 4) and finally, the Lord who rewards one's good deeds and punishes wrong-doing (like a Father), in this world or in a life hereafter.

While many scientists in varying degrees do subscribe to the first three aspects of transcendentalism, not many subscribe to the "societal" aspects of religiosity.⁸ Scientists have their own dilemmas in this respect.

A Jew like Einstein was Jewish because he subscribed to a cultural aspect of the Jewish faith, rather than any fundamentalist belief in the teachings regarding "ideal human conduct" in the Old Testament. He, and those like him, the religious among the scientists, place more value on their belonging to a cultural (and a spiritual) tradition than on fundamentalism. Freud expressed himself similarly, in his preface to the Hebrew translation of *Totem and Taboo*. Referring to the emotional position of an author who is ignorant of the language of holy writ, estranged from the religion of his fathers, he says that if the question were put to him, "Since you have abandoned all these common characteristics ... what is there left to you that is Jewish?" he would reply, "A very great deal, and probably its very essence." He said he "could not now express that essence clearly in words which someday, no doubt, would become accessible to the scientific mind."

The specification of "Ideal Belief and Conduct" unfortunately has almost always led to intolerance, ex-communication, fanaticism and repression, particularly of minorities. There is a divisiveness in the very concept of the chosen people. In its worst manifestations, this divisiveness may sanction murder for religious disagreements, often making a mockery of a religion's own tolerant teachings. In this respect, the late Professor Sir Peter Medawar, Nobel Laureate in Biology and Medicine, in his book *The Limits of Science* (New York: Oxford University Press, 1986) had this to say: "Religious belief gives a spurious spiritual dimension to tribal enmities. The only certain way to cause a religious belief to be held by everyone is to liquidate non-believers. The price in blood and tears that mankind generally has to pay for the comfort and spiritual refreshment that religion has brought to a few has been too great to justify our entrusting moral accountancy to religious belief. By 'moral accountancy' I mean the judgment that such and such an action is right or wrong, or such a man good and such another evil."

The Three Viewpoints of Science

Let us start with Natural Law, which governs the Universe. There are scientists who would take issue with Einstein's view, that there is a sublime beauty about the laws of nature and that the deepest (religious) feelings of man spring from the sense of wonder evoked by this beauty. These scientists would instead like to deduce the laws of nature from a self-consistency and "naturalness" principle, which made the Universe come into being spontaneously. This should be something like the doctrine of spontaneous creation of life and its Darwinian evolution – only now carried to the realm of all laws of nature and the whole Universe. If successful, this, in their view, would lead to an irrelevance of a deity.⁹ Man's spiritual dimension, so-called, would be nothing but a particular manifestation of physiological processes occurring inside the human brain (not fully understood at present), but their hope would be that a molecular basis would one day be discovered for this.¹⁰ Contrasting with this is the view of the anthropic scientist who believes that the Universe was created purposefully with such attributes and in such a manner that sentient beings could arise. These then are the three viewpoints – first the (religious and transcendental) attitude of an Einstein, second the anthropic view (which in a way supports the first), and third the viewpoint of the self-consistent scientist in whose scheme of things the concept of a Lord is simply irrelevant.

Regarding what I have called the secularist sentiments in general, Einstein has this to say: "I am satisfied with the mystery of the eternity of life and with the awareness, and a glimpse of the marvelous structure of the existing world, together with the devoted striving to comprehend a portion, be it ever so tiny, of the Reason that manifests itself in nature. (But) I cannot conceive of a God who rewards and punishes his creatures, or has a will of the kind that we experience in ourselves. The existence and validity of human rights are not written in the stars." Instead his belief was that "the ideals concerning the conduct of men toward each other and the desirable structure of the community have been conceived and taught by enlightened individuals in the course of history." Apart

⁹ I find that creationist creed especially insulting in that while we ascribe subtlety to ourselves in devising these self-consistency modalities, the only subtlety we are willing to ascribe to the Lord is that of the potter's art – kneading clay and fashioning it into a man.

¹⁰ Since the twentieth century has been called "The Century of Science", I wish I could somehow convey the depth of the miracle of Modern Science, both basic and applied. The 20th century has been a century of great synthesis in science – the syntheses represented by quantum theory, relativity and unification theories in physics, by the Big Bang idea in cosmology, by the genetic code in biology and by ideas of plate tectonics in geology, likewise in technology, the conquest of space and the harnessing of atomic power. Just as in the 16th century when the European man discovered new continents and occupied them, the frontiers of science are being conquered one after another. I have always felt passionately that our men and women in Arab-Islamic lands should also be in the vanguard of making these conquests today as they were before the year 1500.

from the subjective character of the opinion, note Einstein's silence about the spiritual dimension of Religion. [...]

Faith and Science

But is the Science of today really on a collision course with metaphysical thinking? The problem if any, is not peculiar to the faith of Islam, the problem is one of Science and Faith in general, at least so far as the Abrahamic religions are concerned. Can Science and Faith at the least, live together in "complementary harmony"? Let us consider some relevant examples of modern scientific thinking.

My first example concerns the "metaphysical" doctrine of creation from nothing. Today, a growing number of cosmologists believe that the most likely value for the density of matter and energy in the Universe is such that the mass of the Universe adds up to zero, precisely. The mass of the Universe is defined as the sum of the masses of matter – the electrons, the protons and neutrinos, which constitute the Universe as we believe we know it – plus their mutual gravitational energies (converted into mass. The gravitational energy of an attractive force is negative in sign). If the mass of the Universe is indeed zero – and this is an empirically determinable quantity – then the Universe shares with the vacuum state the property of masslessness. A bold extrapolation made around 1980 then treats the Universe as a quantum fluctuation of the vacuum – of the state of nothingness.

An attractive idea, but at the present time, measurements do not appear to sustain it. This has led to an ongoing search for a new type of matter – the so-called "dark matter" – which is not luminous to us, but would show itself to us only through its gravity.

We shall soon know empirically whether such matter exists or not. If it does not, we shall discard the whole notion of the Universe arising as a quantum fluctuation. This may be a pity, but this points to a crucial difference between Physics and Metaphysics – experimental verification is the final arbiter of even the most seductive ideas in Physics.

Anthropic Universe

My second example is the Principle of the anthropic Universe – the assertion by some cosmologists that one way to understand the processes of cosmology, geology, biochemistry and biology is to assume that our Universe was conceived in a potential condition and with the physical laws, which possess all the necessary ingredients for the emergence of life and intelligent beings. "Basically this potentiality relies on a complex relationship between the expansion and the cooling of the Universe after the Big Bang, on the behavior of the free energy of matter, and on the intervention of chance at various (biological) levels," as well as on a number of "coincidences" which, for example, have permitted the Universe to survive the necessary few billion years.

Stephen Hawking, the successor of Newton in the Lucasian Chair at Cambridge, in his recent book, *A Brief History of Time: From the Big Bang to Black Holes* (New York: Bantam Press, 1988), has stated the anthropic principle most succinctly:

There are two versions of the anthropic principle, the weak and the strong. The weak anthropic principle states that in a universe that is large or infinite in space and/or time, the conditions necessary for the development of intelligent life will be met only in certain regions that are limited in space and time. The intelligent beings in these regions should therefore not be surprised if they observe that their locality in the universe satisfies the conditions that are necessary for their existence. It is a bit like a rich person living in a wealthy neighborhood not seeing any poverty.

One example of the use of the weak anthropic principle is to 'explain' why the Big Bang occurred about ten thousand million years ago – it takes about that long for intelligent beings to evolve. An early generation of stars first had to form. These stars converted some of the original hydrogen and helium into elements like carbon and oxygen, out of which we are made. The stars then exploded as supernovas, and their debris went to form other stars and planets, among them those of our solar system, which is about five thousand million years old. The first one or two thousand million years of the earth's existence were too hot for the development of anything complicated. The remaining three thousand million years or so have been taken up by the slow process of biological evolution, which has led from the simplest organisms to beings who are capable of measuring time back to the big bang.

Few people would quarrel with the validity or utility of the weak anthropic principle. Some, however, go much further and propose a strong version of the principle. According to this theory, there are either many different universes or many different regions of a single universe, each with its own initial configuration and, perhaps, with its own set of laws of science. In most of these universes the conditions would not be right for the development of complicated organisms; only in a few universes that are like ours would intelligent beings develop and ask the question: 'Why is the universe the way we see it?' The answer is then simple: if it had been different, we would not be here!

The laws of science, as we know them at present, contain many fundamental numbers, like the size of the electric charge of the electron and the ratio of the masses of the proton and the electron. We cannot, at the moment at least, predict the values of these numbers from theory – we have to find them by observation. It may be that one day we shall discover a complete unified theory that predicts them all, but it is also possible that some or all of them vary from universe to universe or within a single universe. The remarkable fact is that the values of these numbers seem to have been very finely adjusted to make possible the development of life. For example, if the electric charge of the electrons had been only slightly different, stars either would have been unable to burn hydrogen and helium, or else they would have not exploded. Of course, there might be other forms of intelligent life, not dreamed of even by writers of science fiction, that do not require the light of a star like the sun or the heavier chemical elements that are made in stars and are flung back into space when the stars explode. Nevertheless, it seems clear that there are relatively few ranges of values for the numbers that would allow the development of any form of intelligent life. Most sets of values would give rise to universes that, although they might be very beautiful, would contain no one able to wonder at that beauty. One can

take this either as evidence of a divine purpose in Creation and the choice of the laws of science or as support for the strong anthropic principle.

Another example of anthropic principle at work is provided by the recently-discovered "electroweak" force. It is interesting to ask why Nature has decided to unify the electromagnetic and weak nuclear forces into one electroweak force. (The electroweak together with the strong nuclear and the gravitational forces constitute the three fundamental forces that we know about in Nature.) One recent answer to this question seems to be that this unification provides one way to understand why in the biological regime one finds amino acids which are only left-handed, and sugars which are only right-handed. (Left and right-handedness refer to the polarization of light after its scattering from the relevant molecules.) In the laboratory, both types of molecules, left-handed as well as right-handed, are produced in equal numbers. Apparently, over biological time, one type of handed molecule decayed into the other type.

According to some scientists, the handedness of naturally occurring molecules is predicated by the fact that electromagnetism (the force of chemistry) is unified with the weak nuclear force – a force which is well-known to be handed (e.g., the weak neutral force exists only between left-handed neutrons and left-handed electrons). This fact, plus the long biological times available for life to emerge, apparently was responsible for the observed handedness of biological molecules in neutrons.

But where does anthropic principle come into this? One indication of this could be as follows: As stated earlier, penicillin molecules produced in the laboratory are both right and left-handed. The right-handed ones among them successfully interfere and destroy the coating of the naturally occurring right-handed molecules on the bacterial skins, which they attack. The penicillin miracle would thus be impossible except for the unification of electromagnetism and weak forces.

Self-Consistency Principle

Finally, there is the third category of scientists, who use "self-consistency" and "naturalness" to motivate the architecture of the Universe. To illustrate self-consistency as applied to Physics, I shall take a recent example.

As an extension of the recent excitement in Physics – that is of our success with the electroweak force, our success in unifying and establishing the identity of two of the fundamental forces of Nature, the electric force and the weak nuclear forces – some of us are now seriously considering the possibility that space-time may have ten dimensions. Within this context we hope to unify the electroweak force with the remaining two basic forces, the force of gravity and the strong nuclear force. This is being done nowadays (1988) as part of "supersymmetric string theories" in ten dimensions. The attempt, if successful, will present us with a unified "Theory of Everything – T.O.E."

Of the ten dimensions, four are the familiar dimensions of space and time. The other six dimensions are supposed to correspond to a hidden internal manifold – hidden because these six dimensions are assumed to have curled in upon themselves to fantastically tiny dimensions of the order of 10^{-33} cm. We live in a 6-dimensional manifold in the 10-dimensional space-time: our major source of sensory apprehension of these extra dimensions is the existence of familiar charges, electric and nuclear, which in their turn produce the familiar electric and nuclear forces.

An exciting idea which may or may not work out quantitatively. But one question already arises: why the difference between the four familiar space-time dimensions and the six internal ones?

So far our major “success” has been in the understanding of why there are ten dimensions in the first place (and not a wholesome number of dimensions like thirteen or nineteen). This apparently has to do with the “quantum anomalies” which plague the theory (and produce unwanted infinities) in any but ten dimensions. The next question, which will arise is this: were all the ten dimensions on par with each other at the beginning of time? Why have the six curled in upon themselves, while the other four have not?

The unification implied by the existence of these extra dimensions curling in upon themselves is one of the mysteries of our subject. At present, we would like to make this plausible by postulating a “self-consistency and naturalness” principle. (This has not yet been accomplished.) But even if we are successful, there will be a price to pay. There will arise subtle physical consequences of such self-consistency, for example, possible remnants, just like the three-degree radiation, which we believe was a remnant of the recombination era following the Big Bang. We shall search for such remnants. If we do not find them, we shall abandon the idea.

Creation from nothing, extra and hidden dimensions – strange topics for late twentieth century Physics – which appear no different from the metaphysical preoccupations of earlier times; however they are all driven by a self-consistency principle. So far as Physics is concerned, mark the insistence on empirical verification at each stage.

Part III

The Essence of Belief

For the agnostic, self-consistency (if successful) may connote irrelevance for a deity; for the believer, it provides no more than an unraveling of a small part of the Lord’s design – its profundity – in the areas it illuminates, it only enhances his reverence for the beauty of the design itself.

But belief has to come first. No one can ordain it: no one can argue it into existence. According to the mystic, “It is a part of the Grace from Allah”. Belief may come from one’s early life – as it did in my case from my father’s teachings

and from his precept – or it may come later, through some experience one may undergo.

But where does one's science come into this?

Heinz Pagels recounts the following story about Feynman, one of the great physicists of our time – perhaps the greatest – who died earlier this year. "He was in a sensory-deprivation tank and had an exosomatic experience – he felt that he came 'out of this body' and saw the body lying before him. To test the reality of his experience, he tried moving his arm, and indeed he saw his arm on his body move. As he described this, he said he then became concerned that he might remain out of his body and decided to return to it. After he concluded his story, I asked him what he made of his unusual experience. Feynman replied with the observational precision of a true scientist: "I didn't see no laws of Physics getting violated."¹¹

I have myself never seen any dichotomy between my faith and my science – since faith was predicated for me by the timeless spiritual message of Islam, on matters on which Physics is silent and will remain so. It was given meaning by the very first verse of the Holy Qur'an after the Opening:

"This is the Book

Wherein there is no doubt

A guidance to the God-fearing

Who believe in the Unseen." (*Al-Qur'an*, 2:2-3)

"The Unseen" – "Beyond the reach of human ken" – "The Unknowable"

There are other good reasons why I am a believer. Maybe Einstein was oblivious to such a need, but personally I do have faith in the efficacy of prayer at times of distress. I could elaborate on this intensely personal thought but I shall forbear to do this. I am also a believer in what Islam teaches me about doing good for mankind. I believe in the Moral Lord; that there is a metaphorical balance; on the one side are placed one's good deeds, on the other one's transgressions against humanity. One is rewarded – already here, on this earth – if one side outweighs the other. My greatest desire before I die is that Allah in His Bounty may grant me the mystical vision so that I too can partake first-hand of what was vouched to the Seers in the past.

As my last thought, I would like to quote again from the Holy Book – a Book, the very sounds of which, in the words of Marmaduke Pickthall, "move men to tears and ecstasy". More than anything else I know of, it speaks of the eternal wonder of the spiritual dimension of life, which I believe is the true message of Abrahamic faiths and their true glory. ▯

¹¹ According to Maurice Bucaille in his essay on "The Bible, The Qur'an and Science," there is not a single verse in the Qur'an where natural phenomena are described and which contradicts what we know for certain from our discoveries in the sciences.

37

Notes on Science and Higher Technology and Development for Iran and the Islamic Countries

"In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed. ... Today we maintain ourselves, tomorrow science will have moved over yet one more step and there will be no appeal from the judgment which will be pronounced ... on the uneducated."

— Alfred North Whitehead

This globe of ours is inhabited by two distinct types of humans. According to the UNDP count of 1983, one quarter of mankind, some 1.1 billion people, are developed. They inhabit 2/5th of land area of the earth and control 80% of the world's natural resources, while 3.6 billion developing humans – the "mustazeffin", the deprived ones – live on the remaining 3/5th of the globe. What distinguishes one type of human from the other is the ambition, the power, the élan, which basically stems from their differing mastery and utilization of present-day Science and Technology. It is a political decision on the part of those (including those in Iran) who decide on the destiny of developing humanity if they will take steps to let the mustazeffin also master and utilize modern Science and Technology. [...]

Science and Technology, a Shared Heritage of Mankind

I may here make a few short remarks about the creation of sciences in Iran. I shall only be able to speak of the Iranian high luminaries in this brief survey.

The undisputable supremacy of Islamic Science (according to Sartori) extends over 350 years. Of these, 250 years are typified by five men from Iran, the physician-philosopher Razi, the geographer Masudi, the mathematician Abul-Wafa, the astronomer-physicist-geologist Al-Biruni, his contemporary, Ibn Sina, and the poet-mathematician Omar Khayyam.

This is perhaps not an accident. The House of Ali has, throughout the centuries, been known for its love of learning and scholarship, which has its basis in the Holy Book and in [Hazrat Ali's] *Nahj-ul-Balaghah*. Imam Ja'far Sadiq's admonitions to the faithful to engage in scientific pursuits are well known. Joined with this were the older traditions of this land – in particular the Christian traditions of Gundeshapur and of the Sabians in the early days of sciences in

Talk given in Tehran, Iran, November 16, 1988.

Islam. This tolerant attitude is clearly shown by the treatment accorded to those from Sabian families, and inheriting their traditions, men like Abdu-Abdalla Al-Battani and Thabit ibn Qurra. (Al-Battani's notable achievement was that "he gave up the old Greek system of chords of angles and adopted the far more convenient trigonometrical proportions known as the sine. With Hipparchus and Ptolemy the Greeks had come close to trigonometry but they had never finally settled on the ratios that Al-Battani adopted, and which, because of their simplicity and conveniences, were to revolutionize the mathematics of triangles used so much in astronomy and surveying, divesting it of some of its previous difficulty.") This notational change was the beginning of Trigonometry as we know it. Ibn Qurra was a physicist who, following Archimedes, wrote on statics and hydro-statics.

After Abdu-Abdalla Al-Battani and Thabit ibn Qurra, Iranian tradition within Islamic Science was best represented by Al-Balkhi Abu Ma'shar (known later to the West as Albumasar), Abu Ma'shar was born at Balkh, an ancient city in the far western regions of Iran in 787 AD, dying in Iraq almost ninety years later. Balkh was an outpost of Hellenistic civilization, which had become a multiracial city where Chinese, Indians, Graeco-Scythians and Syrians intermingled with the Iranian population, and later communities of Buddhists, Hindus, Jews, Manichaeans, Nestorians and Zoroastrians co-existed. Abu Ma'shar was a third-generation member of this intellectual elite, and throughout his life had a sense of Iranian intellectual superiority."

After Abu Ma'shar came Abul Wafa Al-Buzjani, born in the City of Buzjan in 940 AD. Abul Wafa was the great popularizer of tenth-century mathematics. His is the first ever manual on practical arithmetic, *A Book on What is Necessary from the Science of Arithmetic for Scribes and Businessmen*, and a similar one on geometry, *A Book on What is Necessary from Geometric Construction for the Artisan - Science in the Service of Man*. Abul Wafa's popularizations were so eminently serviceable that they were widely circulated in Europe during the Renaissance.

Between 970 and 1000 AD flourished Abu Sahl Al-Quhi; he carried out observations of summer and winter solstices in Shiraz. He was followed by the Iranian Abul Husayn Al-Sufi, who was renowned for his observations and descriptions of the stars and whose book found its way to the West where the author's name was translated as Azophi.

Al-Sufi was followed by a great scientist - whom I always think of as the first of the Moderns in Islam - Abu Rayhan Al-Biruni, who was a native of Armenia. "Born in 973 AD he took to science very early and at seventeen had graduated a ring-dial with half-degree divisions with which he observed meridian altitudes of the Sun. He stayed at Rayy, cooperating with Al-Buzanji - thirty years his senior." Later he was taken to Ghazni in Afghanistan to adorn the court of Sultan Mahmud. "A staunch Muslim, he is said to have invented an instrument

for determining times of prayer, but since it used Byzantine months, a religious legalist abused him as an infidel. 'The Byzantines also eat food,' Al-Biruni is supposed to have replied, 'then do not imitate them in this!'"

After Al-Biruni, one may mention Ghiyath Al-Khayyami, better known to the Western world as the poet Omar Khayyam, born in 1048 AD in Iran. "News of his abilities spread, for in 1070, when he was still only 22 years of age, he was invited by the Seljuk sultan and his grand vizier, to Isfahan to take charge of the observatory there. Al-Khayyami had a plan for calendar reform which advocated a system that would have been in error by no more than one day in 5000 years."

And this brings us to Al-Tusi, and then finally to the towering figure of the "great" ruler Ulugh Beg (1394-1449) and his justly famous observatory.¹² "This was a three-storey building with a giant sextant, the largest astronomical instrument of its type in the world, having a radius of no less than forty meters (132 feet). ... This meant that a precision of something between two to four arc seconds could be obtained, a remarkable achievement for the fifteenth century when one realizes that four arc seconds are equivalent to the width of an ordinary wooden pencil 1.4 km away. ... The director of Ulugh Beg's observatory was Ghiyath Al-Din Al-Kashi. Born in Kashan, Iran, Al-Kashi seems to have lived for a time in penury, trying to muster up patronage for his astronomical and mathematical work, rather than take up ... the study of medicine and practice as a physician. ... Al-Kashi was indeed remarkable, he calculated the value of π to 16 decimal places, and other mathematical ratios with equivalent accuracy."

In this recital of Iranian scientists in the Islamic tradition, one must not forget the great genius Al-Razi who was a medical colossus. "Known to the medieval West as Rhazes, Al-Razi was born at Rayy in Iran around 854 AD. Little personal information about him has survived, but he was for some time director of the hospital in Rayy. He took a critical and non-authoritarian attitude to science. Believing it to be a subject characterized by continual progress – a view he strongly defended against the Aristotelians of his day to whom the summit of science had already been reached in the work of Aristotle – Al-Razi was quite prepared to criticize ancient authorities, whoever they were, and even wrote a book with the title *Doubts Concerning Galen*.

"Al-Razi was a most successful physician and had considerable reputation as a medical author, for he wrote many comprehensive manuals, as well as specialist works on smallpox and measles. However, his non-medical views, his radical rationalism and his anti-religious attacks made him unpopular, a situation summed up later by Ibn Sina when he said that Al-Razi should have confined himself to boils, urine and excrement and have refrained from dabbling in matters beyond the range of his capacity!"

¹² Quotations in this Section are from *The Cambridge Illustrated History of the World's Science*, Colin A. Ronan, 1983.

Ibn Sina himself has "sometimes been called the 'Galen of Islam' because of his encyclopaedic Canon of medicine, which met with great praise and was thought to be impossible of improvement. Its circulation did much to keep Islamic and European medieval medicine in a static condition, but it would be unfair to blame Ibn Sina for this." Ibn Sina, a contemporary of Al-Biruni was, in my opinion, the last of the mediaevalists. He seems to have been as much a philosopher as a medical practitioner; in fact it would probably not be an exaggeration to say that, technically, "he was a better philosopher than Al-Razi, but that Al-Razi was the better physician. Most of Ibn Sina's philosophy was influenced by the Holy Qu'ran and by Aristotle, though it would be wrong to suppose he did not allow science to help form his opinions."

In reciting this work, I have been at pains to emphasize the spirit of tolerance, which was exhibited towards the scientists.¹³ "Despite their missionary zeal and their often fiercely puritanical teachings, the Islamic conquerors were prepared to accept an unrivalled degree of tolerance of the native cultures and religious traditions other than their own. The courts that they established consequently saw a remarkable fusion of the indigenous arts and knowledge. In this way they inherited the science of the Greeks from many Hellenistic cities, as well as the culture of Sassanid Persia."

I shall come back to this topic of tolerance later.

The Widening Gap in Science and Technology

I shall now return to the theme of Science and Technology for development. Today, we are only slowly waking up to the realization that in the final analysis, mastery and utilization of modern Science and Technology is basically what distinguishes the South (and the lands of Islam) from the North. The first remark

¹³ Islam extols the value of revelation above all else: it is the supreme authority in its sphere. "That is not to say that reason is discredited, far from it; the use of the human intellect is prized as one of God's gifts." ... The Mu'tazilites, who emerged after 700 AD in Islam, were aware of this; indeed, they set such store by reason that they went so far as to say that "reason could fathom even the deepest profundities of religious belief" – a statement not made by modern scientists. On the other hand, "the Asharites, whose views first appeared a couple of centuries later, condemned the over-zealous use of reason and its 'adulteration' of religious dogma, and for nearly two centuries the rival schools wrangled with each other until during the twelfth century the Asharite arguments carried the day. There then developed the attitude of passive acceptance – the negation of Ijtihad. This attitude was inevitably inimical to independent scientific thinking" which flourishes in an atmosphere of continual questioning of the foundations of science and an attitude of tolerance towards those who raise such questions. As it was, within Islam, the orthodox intellectual tradition won the day. In this respect, the Shia attitudes with their insistence on Ijtihad may have been nearer to the scientific temper though it is hard to explain on this thesis why science was not created in Iran after the 16th century.

one may make is that on science and technology depend the standards of living of a nation. The widening gap in economies and influence between the nations of the South, the Islamic world, and the North is essentially the Science and Technology gap. Nothing else, in my humble opinion – neither differing cultural values, nor differing perceptions of religious thought, nor differing systems of governance – can explain why today the North can master this globe of ours and beyond.¹⁴

Why does this gap exist and why is it growing? Why is the size of Science and Technology sub-critical and their utilization in the South and particularly, in the Islamic countries so meager? (This, unfortunately, also includes Iran.) I wish to reflect on the problems with you.

My second remark concerns the widespread feeling that the acquiring of Science and Science-based High Technology is hard. I would like to say emphatically that this is not the case. In eloquent phrases, C.P. Snow, in his famous lecture on "The Two Cultures", made the point that Science and Technology are the branches of human experience "that people can learn with predictable results. For a long time, the West misjudged this very badly. After all, a good many Englishmen had been skilled in mechanical crafts for half-a-dozen generations. Somehow, we, in the North, have made ourselves believe that the whole of technology was a more or less incommunicable art."

In Snow's words: "...There is no evidence that any country or race is better than any other in scientific teachability: there is a good deal of evidence that all are much alike. Tradition and technical background seem to count for surprisingly little. There is no getting away from it. It is ... possible to carry out scientific revolution in India, Africa, South-East Asia, Latin America, the Middle East, within fifty years. There is no excuse for Western man not to know this."

The Four Areas of Science and Technology

I shall be concerned primarily with the research and development (R&D) aspects of Science and Technology within our societies in the South and in particular in the Islamic countries, and their utilization for developmental purposes of society.

¹⁴ The role of superior technology in the rise and fall of nations is a relatively neglected subject. Thus, for example, when we think of the British conquest of India, the part played by the superior fire-power of Clive's British-made arms is forgotten. It is equally forgotten that the British "trained" themselves to manufacture such arms. Nor is the role played by the navigational skills (developed at the secret Centre in Sagres in Portugal through the personal interest of Prince Henry the Navigator) which permitted European ships to sail straight into the oceans, rather than hug the coast lines, ever taken into account. Why men like Prince Henry the Navigator arise from time to time among some peoples is, of course, one of Nature's mysteries.

Civilian¹⁵ Science and Technology may perhaps be divided – like in the North – into four categories: a) Basic Sciences; b) Sciences in Application; c) Conventional “Low” Technology; and d) Science-based “High” Technology.

Let us consider each of these areas in turn.

a) *Basic (curiosity-oriented)¹⁶ Sciences.* There are five sub-disciplines among these: 1) Physics (including Geophysics and Astrophysics); 2) Chemistry; 3) Mathematics; 4) Biology; and 5) Basic Medical Sciences.

Research and training for Basic Sciences is conducted in the Universities or in the Research Centers specifically created for this purpose in the North. As a rule, these are funded by National Science Foundations or by Academies of Sciences (which are also responsible for international contacts of scientists.)

So far as developing countries are concerned, by and large we have tended to neglect this area of science, assuming, for some reason, that we could live off the scientific results obtained by others. This has been an unmitigated disaster in that it has also deprived us of men and women who would know about the basics of their disciplines, who could act as references to whom one could turn, to discuss the inevitable scientific problems, which arise when applications of science are made.

b) *Sciences in Application.* Once again, one may list five areas of Sciences in Application. These are: 1) Agriculture; 2) Medicine and Health; 3) Energy (including Nuclear, Fusion, Solar as well as Non-conventional); 4) Environment and Pollution; 5) Earth Sciences (including Meteorology, Minerals, their exploitation, as well as Seismology).

As a rule, Research and Development in Applied Sciences are carried out in the North under the auspices of Research Councils or by private industry. This

¹⁵ Regarding the relationship of Defense and Science, the experience of the Sudanese at the battle of Omdurman (1898) is relevant. “Religious fervor alone is no match for high-tech weaponry. Religious fundamentalism is powerless if it is unable to arm itself with the instruments and weapons that only modern science and technology can provide.” – *The Pakistan Herald* on the Gulf War (September 1988).

¹⁶ The curiosity-orientation of Basic Sciences has been beautifully expressed by David Hilbert, the great Goettingen mathematician (who lived in the early part of the 20th century). According to Dr. Wolfgang Wild, the Minister of Science of the State of Bavaria, Hilbert had the following inscribed for his tombstone: ‘WE MUST KNOW. WE SHALL KNOW.’ The present has been called the greatest century of Basic Science because there have been absolutely fundamental advances made (like “quantum theory, relativity, anti-particles, curved space-time”) in this century with Standard Models elaborated in Particle Physics, in Astrophysics (Big Bang Model), in Earth Sciences (Plate Tectonics) and in Biology (Double Helix Model) during its second half. The task of future generations of researchers from the Third World to improve on these will, I am afraid, be that much harder.

includes Research, Development and Application of Scientific Methodology to developmental problems: this research effort being supplemented with first-class extension services.

What is emphasized more in any given country depends on a nation's priorities.

An essential part of the research process is the free availability of scientific literature.

It is important to realize that the distinction between Basic and Applied Sciences is not absolute. There inevitably are gradations.

c) Conventional Technology. The five sub-areas of this are: 1) Bulk Chemicals; 2) Iron and Steel and Fabrication with Other Metals; 3) Design and Fabrication in Automotive Industries; 4) Petroleum Technologies; 5) Power Generation.

Here no new scientific principles are to be discovered. However, developmental work may be important. This is the traditional area of craftsmanship and skills – the science employed is of yesteryear. Beauty of design, the quality of workmanship and cost are all-important. These are just the areas of so-called “low” technology where developing countries, including the lands of Islam, are not deficient.

This is also the classical area of “negotiated Technology Transfer” and the area on which centrally-planned economies of the Second World as well as the developing countries have placed their strongest emphasis. Any country, which wishes to industrialize will have first to develop one or more of the engineering technologies listed above (as the USSR, Japan and South Korea initially had to do).

d) Science-based “High” Technology. Finally, there are five areas of Science-based “High” Technology which, in the conditions of today, may comprise: 1) New Materials (including composite materials and High Temperature Superconductors); 2) Communication Sciences which consist of two types of sub-disciplines: 2a) Microelectronics (including Development of Software, Microprocessors, Computer-aided Design and eventually, Fabrication of Microchips); and 2b) Photonic (Appendix I) (including Laser and Fiber Optics); 3) Space Sciences; 4) Pharmaceuticals and Fine Chemicals; and finally, for the 21st century, 5) Biotechnology¹⁷ and gene-splicing, so full of promise of a true revolution in the methods of Agriculture, Energy and Medicine.

¹⁷ “Biotechnology thrives on a new knowledge generated by molecular biology, genetics and microbiology, but these disciplines are weak, often nonexistent, in the underdeveloped world. Biotechnology springs from universities and other research institutions – centers that generate the basic knowledge needed to solve practical problems posed by society. But the universities of the underdeveloped world are not research centers. ... And the few creative research groups operate in a social vacuum.

"High" Technology differs from Classical "Low" Technology in that high expertise in the relevant Basic Sciences (like Physics or Chemistry, or Biology, or Mathematics) is crucial. The materials used are minimal in their bulk and size. Very few of the developing countries – with the exception of the "Confucian belt" (like China, South Korea or Singapore) – or Brazil are conscious of the need for or have made progress in "High" Technology even for defense, the general feeling wrongly being that this whole area is beyond us.¹⁸

Why Has Science and Technology Lagged Behind in the South and in the Islamic Countries?

There are three reasons why Science and Technology in the World of Islam and in the Third World countries has suffered.

a) i) *Lack of meaningful commitment towards science, either basic or applied.* By and large, there has been scant realization that science can be applied to development as, for example, there was in Japan at the time of the Meiji Restoration around 1870 when the Emperor took five oaths. One of the oaths set out a national policy towards science – "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness and security of Japan." The consequences of this lack of commitment have been little expenditures on science, whether Basic or Applied, weak universities, few

their results might be useful abroad, but are not locally. ... Biotechnology needs dynamic interactions among the relevant industries. These interactions, however, are weak in countries in which science is perceived as an ornament, not as a necessity. ... Biotechnology requires many highly skilled professionals, but ... underdeveloped nations lack sufficient people well-trained in the pertinent disciplines. ... Economic scarcity and political discrimination induce professionals and graduate students to emigrate or abandon science altogether." (Guest editorial from the journal *Biotechnology*, September 1986).

¹⁸ During the past year or so the bio-revolution has begun to spin off significant new developments in areas of agriculture that are far apart. These include the following: 1) A gene-splicing breakthrough that could shortly revolutionize the economics of dairy farming with the first bovine somatotropin (BST), a genetic growth hormone that offers increases in milk yields of 15 to 20 percent without raising feed costs; 2) Calves can now be 'harvested' from cows at a greatly increased rhythm thanks to embryo duplication techniques that enable a single cow to produce twin calves five times a year; 3) Industrial tissue-culture techniques may soon eliminate the need to grow whole plants. ... Biotechnology specialists, notably the UK company Plant Science, are already producing digitalis, opium, ginseng and pyrethrum by culturing root cells in a fermentation vessel. Big chemical companies like Monsanto and Sandoz have bet ... on their strategies of switching emphasis away from industrial chemicals into biotechnology. Their sights are firmly set on an industry that is forecast to grow from its present turnover of around \$25 billion a year to an annual \$100 billion by the year 2000." – Giles Merritt (November 1987)

research centers for Applied Sciences, sub-critical and isolated communities of scientists (with scant provision for infrastructure and for scientific literature) and weakness in scientific and technological education.

ii) *No commitment to self-reliance in technology.* In technology, by and large, few of our Governments have made it a national goal to strive for self-reliance. The situation may be better for "Low" Technologies but is pitiful where High Technology is concerned for we have paid little heed to the scientific base of high technology, i.e., to the truism that science transfer must always accompany (high) technology transfer, if such transfer is to take place.

b) *Lack of institutional and legal framework.* In respect of a government's commitment to the political action needed, South Korea's institutional and legal enactments may be important to emulate. Dr. Hyung Sup Choi, former Minister of Science and Technology of South Korea, has explained that his Ministry of Science and Technology spearheaded, on the institutional side, the creation of the Korea Institute of Science and Technology (KIST), the Korea Advanced Institute of Science (KAIST), the Korea Technology Finance Corporation (KFTC) and others; while, on the legal side, there was the enactment of several important laws for the development of science and technology. These included: The Science and Technology Advancement Law of 1967 which defined the basic commitment of his government to support science and technology and to provide policy leadership; the Law for the Promotion of Technology Development of 1972, which provided fiscal and financial incentives to private industries for technology development; and the Engineering Services Promotion Law of 1973 to promote local engineering firms by assuring markets on one hand and performance standards on the other. It is this type of care and concern for the utilization of Applied Sciences and Technology, which is needed in all developing countries and in the lands of Islam. Without this no amount of expenditures on Science and Technology is likely to be meaningful for developmental purposes.

c) *The manner in which the enterprise of science has been run.* Science depends for its advances on towering individuals. An active enterprise of Science must be run by working scientists themselves and not by bureaucrats or by those scientists who may have been active once, but have since ossified. (It must be realized in this context that young men and women are attracted to a career in sciences, mostly on account of their innate curiosity and their desire to discover the basic Laws of Nature. This must not be stifled and discouraged in the lands of Islam if we want to keep producing good scientists to work on applied problems and on Science-based High Technology.)

Table I. Defense, education and health expenditures
in US dollars (1984) (as % of GNP)

	Population (× 1000)	GNP (million US\$)	GNP Capita(US\$)	Defense (%)	Edu. (%)	Health (%)
Industrialized countries	1,125,033	11,019,363	9,795	5.6	5.1	4.8
Developing countries	3,651,353	2,697,982	739	5.6	3.7	1.4
Africa*	517,588	356,774	651	4.4	3.8	1.1
Middle East**	100,901	314,518	3,117	18.7	6.2	2.6
South Asia	992,628	266,330	268	3.5	2.8	0.8
Far East***	1,513,771	726,496	480	5.9	3.2	0.9
Latin America and Caribbean	394,718	752,688	1,907	1.6	3.7	1.3

Based on *World Military and Social Expenditures*, by Ruth Leger Sivard, World
Priorities, Inc., Washington D.C., 1987

* Less South Africa

** Less Israel

*** Less Japan

Table II. Industrialized countries' expenditure
on science and technology

Country	Population	GNP per capita (US\$) 1984	Public expenditures in education (% of GNP)	Scientists/ engineers in R&D (per million inhabitants)	Expenditure on R&D* (% of GNP)
France	55.17 (1985)	9,540	5.8 (1983)	1,363 (1980)	2.25 (1980)
Federal Republic of Germany	61.02 (1985)	10,940	4.6 (1984)	2,178 (1984)	2.54 (1984)
Japan	120.75 (1985)	11,300	5.6 (1984)	4,436 (1984)	2.65 (1984)
Netherlands	14.48 (1985)	9,290	6.9 (1984)	2,170 (1984)	1.97 (1984)
U.K.	56.49 (1984)	8,460	5.2 (1984)	1,545 (1980)	2.3 (1984)
U.S.A.	1,293.30(1985)	16,690	—	—	2.69 (1984)

*Based on UNESCO statistics (1987). (These figures may include: application, diffusion and commercialization and venture capital for technology provided by some governments as well as export credits to high technology companies.)

The Sub-Critical Size of Science and Technology in the South and in the Lands of Islam

a) According to an empirical law discovered by the late Professor Jolla Price of Yale University, with few exceptions, a country's output of scientific research is directly proportional to its spending on Science and is correlated with its GNP. Thus, one of the more revealing indices of the size of Third World Science is the funding, which the South provides for Research and Development. To appreciate this, one has to look at Tables I, II and III which give the Defense, Education, Health and Science Expenditures as percentages of GNP, both in the South and in the lands of Islam, in contrast to the spending in the North.

The point about the Tables is the following: Both the industrialized and the developing countries spend on the average 5.6 % of their respective GNPs on defense. The educational expenditures are also similar – 5.1% for the industrialized versus 3.7% for the developing countries. For health it is 4.8% for the industrialized versus 1.4% for the developing countries – admittedly, a difference, but not as striking as for Science and Technology. The figures for this latter differ from each other in general by nearly an order of magnitude.

b) A second index of the sub-critical size of Science and Technology is the number of those engaged actively in this activity in the Third World. The UNESCO figures once again paint a different picture for the South and the North. In the North, an order of 2000 or more inhabitants per million are engaged in Research and Development, while those similarly engaged in the South seldom exceed more than a few hundred. Once again, there is a factor of at least one or two orders of magnitude between the respective numbers. The Chinese figures in this context are revealing. According to Professor Lu Jiaxi, former President of the Chinese Academy of Sciences – speaking on Chinese Science at the Second General Conference of the Third World Academy of Sciences in Beijing in September 1987 – the Chinese had fewer than 500 researchers in 1949 altogether, less than one per million of population. The situation in most developing countries today is similar to that in China in 1949. (There are now 300,000 researchers in China and the country is approaching international norms, with an increase of a factor of 600 in forty years.)

The socialist regimes by and large have taken to Science and "Low" Technology as a Religion, and with the same fervor. (They are slowly waking up to the possibilities in "High" Technology.)

Table III. Estimated expenditure for research and development in 1980 as percentage of GNP (Selected Countries)

Asia		Latin America & Caribbean		Africa	
India	0.9	Brazil	0.6	Algeria	0.3
Pakistan	0.2	Argentina	0.5	Nigeria	0.3
Bangladesh	0.2	Peru	0.2	Egypt	0.2
Sri Lanka	0.2	Chile	0.4		
Indonesia	0.3	Mexico	0.6		
Philippines	0.2	Cuba	0.7		
Singapore	0.5	Venezuela	0.4		
Republic of Korea	1.1				
Iran	0.5*				
Iraq	0.1*				

From UNESCO Statistical Yearbook 1987

*1975 figures.

The Present Picture of Science in the Islamic Countries

What is the picture of science and technology in the Islamic Commonwealth? According to A.B. Zablan, who taught at the American University of Beirut, an analysis of these and similar figures reveals that at least as far as the science of physics is concerned, the Islamic community is around one-tenth in size and one-hundredth in scientific creativity in research publication, compared to the international norms. Pakistan, considered as one of the scientifically advanced of Islamic countries, had in 1983 nineteen universities, but only thirteen professors of physics, and a total of forty-two physics Ph.D. teachers and researchers in all its universities – this for a population of ninety million. To compare the corresponding numbers at one college at one university in the United Kingdom – the Imperial College of Science and Technology – there are twelve professors and more than one hundred and twenty-five researchers. [...]

Steps Needed to Make Science and Technology Strong in Developing Countries and in the Countries of Islam

Why do we neglect science and technology based on science so far as development is concerned? First and foremost, there is the question of national ambition. Let me say it unambiguously. Countries of the size of Iran, or Egypt, or my own country, Pakistan, have no science communities geared to development because we do not want such communities. We suffer from a lack of ambition towards acquiring science, a feeling of inferiority towards it, bordering sometimes even on hostility. [...]

a) *Generous patronage and expenditures on science and technology.* No Science and Technology is possible without a nation spending an inescapable minimum of funds on it. In the industrialized countries, as a general rule, some 2-2.5% of GNP is made available – by the State as well as by private industry – for

Research and Development in the four broad areas mentioned earlier. So far as absolute expenditure is concerned, the funds spent on Basic Sciences Research in the North amount to some 4-10% of a nation's educational budget – taken as a unit – while roughly the same amount is spent on Applied Science Research, and twice as much on Research and Development related to “High” Technology. If the developing countries adopt, as a desirable minimum, the lower figure of (4+4=8%) of their educational expenditures to be spent on Science (both Basic and Applied) including training for research as well as for international contacts, this should give us the colossal figure of 7.25 billion dollars from the South's own resources – according to the estimates made by the Third World Academy of Sciences (TWAS). For Science-based technology, one may consider a further figure of 8% of the educational expenditure, bringing the desirable minimum total for Science and Technology to around 4.5 billion dollars for the South as a whole. (No Science-based development will accrue, unless we make these basic outlays. Once again it is to be emphasized that this is not a recommendation to diminish the education budget but to find the additional spending on Science and Technology through general belt-tightening).

b) *The modalities of growth of sciences and technology, including training and international contacts.* If one were charged with running Science in a typical developing country of modest size, one would allocate in the first place (extra) funds roughly equal to 4% of a country's education budget to build up Basic Sciences in the universities, to maintain international contacts, and for the appropriate training of cadres of scientists and technicians so as to assure a critical size. At the same time, one would commission and blue-print a comprehensive plan for Applied Sciences, allocating and spending (in the third or the fourth year) extra funds roughly equal to another 4% of the education budget for these. (What one spends on, depends on a nation's priorities and could be in one or more of the following areas: agriculture, health, livestock, energy, materials and minerals, environment, soil sciences, oceans, communications. I am assuming that trained manpower has by now been assembled.)

Finally, one would spend on training of personnel and on Research and Development in the area of Science-based high technology, sums which are equivalent to 8% of the education budget, as the quickest way to produce wealth, making up the desirable minimal total of 16% of the education budget after a lapse of six years or so. (We are assuming, of course, that there would additionally be the crucially important Ministry of Conventional Technology to take care of “Low” as contrasted to “High” Technology and to give it its requisite inputs.)

c) *Reciprocal responsibility of scientists and technologists.* A parallel sense of responsibility must also be instilled by and into the scientists and the technologists in developing countries. Scientists and technologists are an insignificant proportion of our populations. They constitute a particular social

subculture and as such occupy a particular niche in every society. The relevance of this niche is a function of its explicit articulation and integration with the national development process. The top-ranking scientist and technologist must, in particular, feel that they are part of a team, which is engaged on an exciting venture. Such an articulation depends upon the conscious involvement of the scientific and the technological community in the tasks of socioeconomic development, as well as upon the image of science and technology (and of scientists and technologists) in the minds of the non-scientific population – in particular of decision-makers (politicians, entrepreneurs, managers). This two-way interaction depends as much on the attitude of scientists and technologists towards development as upon the reciprocal attitude of the administrators towards the scientists.

d) *Creation of a favorable science and technology climate.* In the words of Dr. Hyung Sup Choi: "Science and Technology development gains momentum when a suitable environment for its popularization is created. The creation and promotion of such an environment is a prerequisite for science and technology development, particularly in a country where social and economic patterns and customs are bound by tradition. Korea has launched a movement for the popularization of science and technology as an integral part of its long-range science and technology development plan. The movement aims to motivate a universal desire for scientific innovation in every one in all aspects of their lives. It has been led by the Ministry of Science and Technology, the Korea Science Promotion Foundation, and the Saemaul Technical Service Corps in co-operation with concerned government agencies, industry, academic circles, and the mass-communication media. This movement is in no way conceived as the special province of scientists and engineers, although this group can provide key support and resources in view of its pertinent talent and knowledge."

Renaissance of Sciences in Islam

a) *Can we turn the pages of history back and once again lead in sciences?* I would humbly like to submit that we can – provided society as a whole, and our youth in particular – come to accept this as a cherished goal, in keeping with our ideological beliefs, and in keeping with our own experience of early centuries of Islam. We must, however, remember that there are no short cuts to this Renaissance. In the conditions of today a nation's youth have to be fired and the nation commit itself with a passionate commitment to this goal; it must impart hard scientific training to more than half of its manpower; it must pursue basic and applied sciences, as well as self-reliant low and high technology.

This was done in the Soviet Union sixty years ago when the Soviet Academy of Sciences, created in the 18th century by Peter the Great, was asked to expand its numbers. Now it boasts of a self-governing community of half a million scientists working in its institutes, with priorities and privileges accorded to them in the Soviet system that others envy. [...]

A similar emphasis on sciences is now being placed in a planned manner and at a frantic speed by the People's Republic of China, with a defined target of catching up and surpassing the United Kingdom in space sciences, in genetics, in microelectronics, in high energy physics, in fusion physics and in the control of thermo-nuclear energy by the end of this century. The Chinese have recognized that all basic science is relevant science; that the frontier of today is tomorrow's application and that they must remain at the frontier. In this context one may recall that the GNP of the Islamic nations exceeds that of China, while the human resources are not significantly smaller. And China has a lead of no more than a few decades over us in sciences. Shall we collectively set ourselves the goal, at the least, of emulating the Chinese?

The societies I have mentioned are not seduced by diversionary slogans of "Japanese" or "Chinese" or "Indian" science. They recognize that though the emphasis in the choice of disciplines on which to research may differ from society to society, the laws, the traditions and the modalities of science are universal. They do not feel that the acquiring of "western" science and technology will destroy their own cultural traditions; they do not insult their own traditions by believing that these are so weak.

b) *Tolerance.* I have spoken earlier of patronage for sciences. One aspect of this is the sense of security and continuity that a scientist-scholar must be accorded for his work. Today, an Arab or an Indian or any other Muslim scientist and technologist – and on Zahlan's count, there are more than thirty thousand of them – can be sure of a life-long welcome in the United States or in the United Kingdom if he possesses the requisite qualities. He will have security, respect and equality of opportunity for his work and advancement. We must ask ourselves if this is true within our societies. We must ask ourselves if we discriminate against, or even at times terminate the services of scientists because they happen to have originated in a country with which our government may have temporarily differed.

There is no question but that the United States of America built up its present ascendancy in sciences in a telescoped period of time by welcoming the community of scientists who had to flee Europe in the inter-war years. But this welcome was not superficial; these men were accorded rights of citizenship; there was no expectation that they would return to their countries of origin after "their tour of duty" was finished. These scientists learned English, settled and raised families in the United States. Hitler drove all Jewish scientists out of Germany. The scientists who remained tried but failed to make an atomic weapon. There is the well-known story of Enrico Fermi, who went to USA just after the ceremony in Stockholm, paying his own and his family's fare from the Nobel prize he was awarded in December 1938. In the USA he was commissioned to build the first atomic reactor, while still waiting for official clearance for his immigration: the higher authorities dared not accelerate these procedures for fear of alerting the Axis intelligence. But all security rules were

bent, for the US had faith in Fermi. The question is – are our countries making a similar bid for at least the highest level among the scientists they have imported? Do we accord such men security, human toleration and personal peace: do we welcome them with open arms, so that they can build up schools of research with the fullest involvement?

c) *Need for a Commonwealth of Science in Islam.* In my view, there is need of a Commonwealth of Science for the Islamic countries, even if there may be no political commonwealth yet in sight. Such a Commonwealth of Science was a true reality in the great days of Islamic Science, when Central Asians like Ibn-Sina and Al-Biruni would naturally write in Arabic, or their contemporary and my brother in physics, Ibn-al-Haitham, could migrate from his native Basra in the dominions of the Abbasi Caliph to the Court of his rival, the Fatimid Caliph, assured of receiving respect and homage, notwithstanding the political and sectarian differences, which were no less acute then than they are now. A new Islamic Commonwealth of Science needs conscious articulation, and recognition once again, both by us, the scientists, as well as our governments. Today we, the scientists from the Islamic countries, constitute a very small community – one-hundredth to one-tenth in size, in scientific resources, and in scientific creativity compared to international norms. At the least, we need to band together, to pool our resources, to feel and work as a community, at science centers which are run for all Islamic countries. To foster this growth, could we possibly envisage from our governments a moratorium, a compact, conferring of immunity, for say the next twenty-five years, during which the scientists from within this Commonwealth of Science, this Ummat-ul-Ilm, could be treated as a special sub-community with a protected status, so far as internal political sectarian differences are concerned, just as was the case in the Islamic commonwealth of Sciences in the past? [...]

d) *Summary of recommendations.* To summarize, the renaissance of sciences within an Islamic Commonwealth is contingent upon five cardinal preconditions: passionate commitment, generous patronage, provision of security and tolerance, self-governance, and internationalization of our scientific enterprise.

That such an orientation towards science will be resisted by some should not be doubted. The tragedy is that such people wrongly claim to speak in the name of the Islamic theological tradition. Even today there are those whose views on science are represented by the following quotes from a widely circulated Islamic monthly – *The Arabia* – published in London.

Was the science of the Middle Ages really 'Islamic' Science?

The story of famous Muslim scientists of the Middle Ages such as Al-Kindi, Al-Farabi, Ibn-al-Haitham and Ibn Sina shows that, aside from being Muslims, there seems to have been nothing Islamic about them or their achievements. On the contrary their lives were distinctly un-Islamic. Their achievements in medicine,

chemistry, physics, mathematics and philosophy were a natural and logical extension of Greek thought.

Al-Kindi held Mutazalite beliefs. Ibn-al-Haitham was another Aristotelian. In the words of one scientific historian, De Boer, "Al-Haitham considered the various doctrines and came to recognize in almost all of them more or less successful attempts to approximate the truth." Truth to him was only that which was presented as material for the sense perception. No wonder that he was generally regarded as a heretic, and has been almost totally forgotten in the Muslim world.

The writer goes on to castigate my work on the unification of fundamental forces as "pantheism" and therefore un-Islamic and heretical. I am proud to be a case together with Al-Kindi, Al-Razi, Ibn-al-Haitham and Ibn-Sina but I do protest against the attribution of pantheistic motives to myself.

There is no question about it, we do not speak the same language. After this incredible outburst against men in whose work most Muslims take pride, the writer goes on to advocate a policy of the same type of isolationism that destroyed our scientific tradition in the past:

Countries that have escaped the political dominance of the West have done so by unilaterally imposing an eclectic isolation on themselves. This is the case with both Russia and China, and would also have been the case with Japan had not Commander Perry made the opening of trade ties between Japan and America a precondition for postponing the conquest of Japan. ...

Muslim countries must develop a science policy that makes them capable of dispensing with the need to import both western science and western technology.

I could not agree more, so far as technology is concerned. But for science, one is again reminded of the story of Al-Biruni I have told before, who was accused by a contemporary divine of heresy when he used the Byzantine (solar) calendar for an instrument he had invented for determining the times of the prayers. Al-Biruni retorted by saying, "The Byzantines also eat food. Then do not imitate them in this!"

Science and Technology Education Policy in the Third World and the World of Islam

i) *Islamic ethos and science education.* The Holy Book places strong emphasis on *Al-Tafakkur* (reflection on and discovery of laws of nature) and *Al-Taskheer* (acquiring a mastery over nature through technology). Taking this and the realities of modern living into account, one of the first requisites of the Ummah in Islam is to encourage scientific and technological education from the secondary and the tertiary, through the university stages.

In the following Table IV, I give the World Bank figures for educational enrolment for the Islamic countries.

As can be seen from the Table, there are wide variations between the different countries, as well as between the industrialized and the developing countries. The starkest variations, however, are in the average numbers we

educate between the ages of 12-19 (secondary education level) and the ages between 20-24 (university education). The low-income developing country averages ("the real South" with a GNP/capita less than \$400) are particularly low compared with those of the developed countries (22-37% versus 93% for secondary education and 5% versus 39% for university education). For Iran, the figures for secondary and tertiary education are 46 and 5 respectively, to be compared with 93 to 31 for the developed countries. This means that at the learning stage, a student in most of our countries is ill equipped for the modern world. It is important not only to cure this imbalance, but also to change the thrust of our secondary education. The following observations are relevant in this context.

ii) *Secondary education.* After a period of compulsory lower-secondary education (which may be completed at the age of fifteen or so) most modern societies provide for two parallel educational systems. Using the UK terminology of the 1970s these two systems may be called, 1) the system of professional education ("blue collar" education) comprising technical, vocational, agricultural and commercial courses, 2) the system of higher education ("white collar" education) comprising courses which lead on to the university level, in the sciences, engineering, medicine and the arts.

iii) A major structural failing of the Third World (and Islamic countries') educational system has been that, in general, no credible professional ("blue collar") system has developed. It is true that a half-hearted system of polytechnic institutions and vocational schools has been built up in recent years in a number of Third World countries, but this system has had scant prestige attached to it. (As a general rule, such systems have been run by the Ministries of Labor and Employment, rather than the Ministries of Education.)

iv) To see how inadequate such a system has been, one may recall that in industrialized countries the proportion of those enrolled for the two streams is of the order of 50:50. In the Third World, however, the proportion of the professional versus the university level (blue versus white collar) enrollment is normally of the order of 10:90. This preponderance of technologically illiterate is the major cause of unemployment and of the Third World's and the Islamic countries' technical backwardness.

v) One of the main educational tasks before us is to change this ratio of 10:90 to 50:50. (In the conditions of today, the blue-collar "professional system" should

Table IV. Net enrolment in Islamic countries and countries with large Muslim minorities 1985*

	Primary (6-11 yrs of age) %	Secondary (12-19 yrs of age) %	Tertiary (20-24 yrs of age) %	ICTP visitors 1970-88 (30 June)
Low-income economies (GNP/Cap less than 400 US\$)				
	99 w	34 w	-	
1. Gambia	75**	20 **	-	4
2. Burkina Faso	32	5	1	15
3. Bangladesh	60	18	5	319
4. Mali	23	7	1	51
5. Tanzania	72	3	-	118
6. Somalia	25	17	-	21
7. Central Africa Rep.	73	13	1	3
8. India	92	35	-	1,988
9. Sierra Leone	-	-	-	70
10. Sudan	49	19	2	241
11. Pakistan	47	17	5	598
12. Mauritania	-	-	-	15
13. Senegal	55	13	2	63
14. Afghanistan	-	-	-	11
15. Chad	38	6	-	2
16. Guinea	30	12	2	38
TOTAL				3,557
Middle-income econ. Lower middle-income (GNP/Cap between 400 and 1600 US\$)				
	104 w	49 w	14 w	
	104 w	42 w	13 w	
17. Yemen PDR	66	19	-	4
18. Indonesia	118	39	7	167
19. Yemen Arab Rep	67	10	-	44
20. Philippines	106	65	38	107
21. Morocco	81	31	9	159
22. Nigeria	92	29	3	533
23. Egypt	85	62	23	962
24. Cameroon	107	23	2	32
25. Turkey	116	42	9	585
26. Tunisia	118	39	6	85
27. Jordan	99	79	37	140
28. Syria W. Arab Rep	108	61	17	113
29. Lebanon	-	-	-	124
TOTAL				3,055
Upper middle income (GNP/ Cap between 1600 and 4000 US\$)				
	105 w	57 w	16 w	
30. Malaysia	99	53	6	179
31. Algeria	94	51	6	169
32. Oman	89	32	1	-
33. Iran, Islamic Rep	112	46	5	299
34. Iraq	100	55	10	137
TOTAL				784

	Primary (6-11 yrs of age) %	Secondary (12-19 yrs of age) %	Tertiary (20-24 yrs of age) %	ICTP visitors 1970-88 (30 June)
Developing countries	101 w	39 w	8 w	
Oil exporters	107 w	44 w	10 w	
Exporters of manufactures	109 w	40 w	—	
Highly indebted countries	104 w	47 w	16 w	
Sub-Saharan Africa	75 w	23 w	2 w	
High income oil exporters	86 w	56 w	11 w	
35. Saudi Arabia	69	42	11	69
36. Kuwait	101	83	16	110
37. Bahrain	111 **	86 **	10 *	3
38. United Arab Morocco	99	58	8	1
39. Libya	127	87	11	123
TOTAL				306
GRAND TOTAL				21,116
Industrial market economies (GNP/Cap higher than 4000 US\$)				
	102 w	93 w	39 w	
1. Spain	104	91	27	275
2. Ireland	100	96	22	42
3. New Zealand	106	85	35	5
4. Italy	98	75	26	4,142
5. United Kingdom	101	89	22	1,350
6. Belgium	95	96	31	357
7. Austria	99	79	27	408
8. Netherlands	95	102	31	290
9. France	114	96	30	1,150
10. Australia	106	95	28	78
11. Germany, Fed. Republic	96	74	30	1,439
12. Finland	104	102	33	42
13. Denmark	98	103	29	116
14. Japan	102	96	30	314
15. Sweden	98	83	38	390
16. Canada	105	103	55	211
17. Norway	97	97	31	41
18. United States	101	99	57	2,391
19. Switzerland	—	—	22	373
TOTAL				13,414

* From: *World Development Report 1988*, World Bank, 1988.

** From: *UNESCO Statistical Yearbook*, 1987.

w: weighted average for all countries (Islamic, countries with large Muslim minorities and others) belonging to the income category concerned.

be accorded equal status with the better-known "liberal" educational system and should include courses on modern materials (including metal fabrication), as well as courses on microelectronics.

vi) Our first task will be to bring a measure of prestige to the professional system of education. One will need to give serious consideration to the institution of National Certificates – or preferably, decide to identify these with the prevailing awards. What we have in mind is this. Parallel with the present system of education in arts and sciences, we should create a second – the professional system of education. Each award – the matriculation, or the Bachelor's Degree – may be obtained either after the present "liberal" courses in arts or sciences as now, or after technical, agricultural, or commercial courses from a polytechnic, an agricultural, or a commercial school. So far as job opportunities in administrative services are concerned, all Bachelor's Degrees (general, technical, or commercial) – likewise all matriculates of whatever variety – would count as equivalent. Only thus will the exclusive hold on the public mind of the present prestigious "liberal" system of education be broken.

vii) *University level.* The proportion of those following Science and Engineering versus those following the arts at the "liberal" university level is of the order of 50:50 in most of the industrialized countries. This is certainly not the case for most developing countries, nor for the Islamic countries. One must aim at 50:50 ratio.

viii) *Specialization.* One proposal, which may be considered in this context is that of specialization. Could, for example, a consortium of Universities in the US and UK be helped by their governments and encouraged to take care of University Science in all those developing countries who desire this? Could the Netherlands and Belgium look after the building up of libraries and laboratories? Could Germany and Japan look after technical education at all levels? Could Scandinavia look after the scientific aspect of ecology? Could Switzerland and Austria (with their well-known pharmaceutical expertise) look after medical education? Could Italy, with its experience of setting up International Centers in Physics and Biotechnology, look after the creation of similar institutions in all disciplines of science in centers within developing countries? Could the US, Canada, Australia, New Zealand look after education for agriculture and education for prospecting? Could one envisage the USSR taking care of primary, secondary and vocational education? Could France, Canada and Spain carry out all these actions for the French and Spanish speaking developing countries if desired by them? This is merely an illustration of what a possible division of the relevant tasks could be. Eventually, of course, these suggestions would have to be tailored and modified when detailed projects are elaborated.

ix) What I have in mind is something patterned along the lines of the success which India achieved in the decade of the sixties when it created four Indian Institutes of (Science and Technology). The one in Kanpur was created by a US consortium of universities, which helped to raise and furnish it, besides supplying the higher cadres of teaching staff for a number of years. The one in Delhi was helped by a consortium of British universities; the one in Bombay by the USSR and the one in Madras by the Federal Republic of Germany. Each nation helped to build up the institute under Indian auspices, contributed staff and left behind a tradition in teaching and research, which has continued even after the original contracts have expired. There was a healthy rivalry between the donor nations vying with each other; this guaranteed the excellence and standards of quality. What I envisage in the proposal above is something like this except that it is to be carried out on a much wider canvas. One would hope that by the year 2000, if the plans are drawn up now, many of the objectives I have mentioned will have been achieved. In this, one must not forget that (even though not affluent enough to contribute materially) countries like China, India, Brazil, Egypt, Nigeria, Yugoslavia and many others could make highly valued intellectual inputs to these specialized efforts.

International Modalities for the Growth and Utilization of Science and Technology

i) *United Nations agencies and international centers for science.* In multilateral co-operation, the United Nations agencies, including the United Nations University, should have a prominent role in building up scientific infrastructure in their areas of competence. Developing countries need international research institutions on the applied side like the Wheat and Rice Research Institutes in Mexico and in the Philippines and the International Centre for Insect Physiology and Ecology in Kenya. There is also the experience on the basic side, of UNESCO and IAEA in relation to the International Centre for Theoretical Physics, Trieste (with visits of 4000 physicists last year, 2500 of them from developing countries and 1500 from the industrialized countries; forty-nine visitors came from Iran and nine hundred and fifty-four from the Arab and Islamic countries), or of UNIDO for the International Centre for Biotechnology and Genetic Engineering at Trieste and Delhi, on the applied side. These Centres are run by the scientists for the scientists. The South should, at the least, utilize those trained at these Centres and urge other United Nations Organizations to set up international centers in disciplines relevant to their competence.

In this context, there is the proposal to create in Trieste for the developing countries an International Centre for Science which shall have five components: 1) the existing International Centre for Theoretical Physics; 2) the existing International Centre for Genetic Engineering and Biotechnology; 3) a new International Centre for High Technology and New Materials; 4) a new International Centre for Chemistry, both Pure and Applied; and finally 5) a new

International Centre for Earth Sciences (for research in and for imparting knowledge of the recent advances in geology, prospecting, soils, as well as for the environmental aspects of Earth Sciences, including Meteorology). The International Centre for Science will be created with United Nations sponsorship by the Italian Government.

The Third World Academy of Sciences – a non-governmental organization – convened in October 1988 the first meeting of the third World Network of Scientific Organizations. This meeting brought together fifteen Ministers of Science, Technology and Higher Education, twelve Presidents of Academies of Science plus seventeen Chairmen of Research Councils from thirty-eight Third World countries. We decided to create a scientific organization for looking after global science – and also, inter alia, act as a pressure group for Science within the Third World – on the pattern of the Group of '77. The current membership of the Network consists of eighty-nine Ministries of Science, Technology and Higher Education plus Academies plus National Science Research Councils from sixty Third World countries. The discussions focused on the Third World joint action on global scientific problems like Fusion Research, the Human Genome problem, the Greenhouse Effect, and Waste Disposal in the South.

ii) The Third World Academy of Sciences has as its Fellows (or Associate Fellows) one hundred and thirty-nine of the Third World's most prestigious scientists from fifty countries (ten of them Nobel Laureates born in the Third World). The Academy is proud to have among its membership two Fellows from Iran, Dr. Farrokh Saidi and Dr. Yousef Sobouti and as an Associate Fellow, Dr. Ali Javan from MIT. The Academy has among its projects one for South-South collaboration in Sciences. More than two hundred Fellowships have so far been made available by the Scientific Institutions in Argentina, Brazil, Chile, China, Colombia, Ghana, India, Iran, Kenya, Madagascar, Mexico, Vietnam and Zaïre for such visits. The Third World Academy of Sciences pays for the travel of Third World scientists to a third world country. Clearly, the efforts of the Third World Academy of Sciences – a Non-Governmental Organization – in this direction need to be enhanced a thousand-fold.

iii) *Science Foundations in Islam.* In 1973, the Pakistan Government, on my suggestion, requested the Islamic Summit in Lahore to sanction at least one Foundation for Science for Islam, equal in size to the Ford Foundation, with a capital of one billion dollars. Eight years later, in 1981, such a Foundation was created but – I believe – with just fifty million dollars promised instead of the one billion requested. It may have been more charitable not to have deceived ourselves by this creation. [...]

12. Concluding Remarks

Why am I so passionately advocating our engaging in this enterprise of creating scientific knowledge? This is not just because Allah has endowed us

with the urge to know, this is not just because of the conditions of today, this knowledge is power and science in application the major instrument of material progress; it is also that as members of the international world community, one feels that lash of contempt for us – unspoken, but still there – of those who create this knowledge.[...]

I have addressed in this paper three categories of “those with the word” among us: these are the affluent whom Allah has endowed with substance, our ministers and princes responsible for our science policies, and our men of religion.

As I have repeatedly emphasized, science is important because of the underlying understanding it provides of the world around us, of the immutable laws and of Allah’s design; it is important because of the material benefits and strength in defense its discoveries can give us; and finally it is important because of its universality. It could be a vehicle of co-operation of all mankind and in particular among the Islamic nations. We owe a debt to international science, which, in all self-respect, we must discharge. ...

And let me finally repeat, for those who are worried about the impact of modern science on Islam, that to know the limitations of science, one must be part of living science; otherwise one will continue fighting yesterday’s philosophical battles today. Believe me, there are high creators of science among us – and potentially among our youth. They have the strongest urge to join in the adventure of knowing. Trust them; their Islam is as deeply founded, their appreciation of the spiritual values of the Holy Book as profound, as anyone else’s. Provide them with facilities to create science in its standard norms of inquiry. We owe it to Islam. Let them know science and its limitations from inside. There truly is no dissonance between Islam and modern science.

Let me conclude with two thoughts. One is regarding the urge to know. As I said before, the Holy Qur’an and the teachings of the Holy Prophet emphasize the creating and the acquiring of knowledge as bounden duties of a Muslim, “from cradle to the grave”. I spoke of Al-Biruni who flourished at Ghazna one thousand years ago. The story is told of his death by a contemporary who says: “I heard Al-Biruni was dying. I hurried to his house for a last look; one could see that he would not survive long. When they told him of my coming, he opened his eyes and said, “Are you so and so?” I said “Yes.” He said: “I am told you know the resolution of a knotty problem in the laws of inheritance of Islam.” He alluded to a well-known puzzle. I said, “Abu Raihan, at this time?” And Al-Biruni replied, “don’t you think it is better that I should die knowing, rather than ignorant?” With sorrow in my heart, I told him what I knew. Taking my leave, I had not yet crossed the portals of his house when the cry arose from inside. Al-Biruni is dead.” ■

Appendix I. (continued)

Member states		ICTP			TWAS		Research grants 1986-88	GNP* (SUS billions) 1985	Population* (millions) 1985
	No. of scientific visitors 1970-1988 (30 June)	External activity 1986-88	Visits to Italian labs 1983-88	Federation agreements 1988	Visits to Italian labs 1986-88	South-South fellowships 1986-88			
Group VI									
Burkina Faso	15	-	-	-	-	-	-	1.10	7.80
Cameroon	32	-	-	1	-	1	-	8.30	10.20
Central African Rep.	3	-	-	-	-	-	-	6.20	2.580
Chad	2	-	-	-	-	-	-	n.a.	5.00
Comoros	2	-	-	-	-	-	-	0.10	0.40
Cote d'Ivoire	29	5	-	3	-	-	-	6.20	10.00
Ethiopia	96	1	1	2	2	1	-	4.60	47.27
Gabon	5	-	-	1	-	-	-	3.30	1.00
Gambia	4	-	-	-	-	-	-	0.17	0.70
Guinea	38	-	2	3	-	3	-	1.90	6.00
Guinea-Bissau	-	-	-	-	-	-	-	0.15	0.90
Mali	51	1	4	3	-	-	-	1.10	7.50
Mauritania	15	-	-	1	-	-	-	0.70	1.70
Niger	11	-	-	-	-	-	-	1.30	6.40
Nigeria	533	8	32	20	8	4	14	75.9	99.70
Senegal	63	2	1	1	-	-	-	2.40	6.60
Sierra Leone	70	1	2	1	-	3	3	1.40	3.70
Somalia	21	-	5	1	-	-	-	1.50	5.40
Togo	34	-	-	-	-	-	-	0.75	3.00
Uganda	58	-	-	-	1	-	-	n.a.	15.40
GRAND TOTAL	5,743	63	135	170	34	31	56		

*From *World Bank Atlas*, 1987.

From 1986 to 1988 TWAS has provided scientific books and journals, as well as spare parts for scientific equipment to twenty-seven countries and financially supported fifty-five scientific meetings in fourteen countries.

**Figures for 1983.

Appendix II. R&D Manpower in Islamic countries

Country	Population in 1985* (millions)	R&D scientists and engineers**
Afghanistan	17.02 (1983)	330*** (1966)
Algeria	21.80	242*** (1972)
Bahrain	0.42	-
Bangladesh	100.6	-
Burkina Faso	7.8	-
Cameroon	10.2	-
Chad	5	85*** (1971)
Comoros	0.4	-
Djibuti	0.4	-
Egypt	47.1	19,941 (1982)
Gabon	1	8*** (1970)
Gambia	0.7	-
Guinea	6	1,282 (1984)
Guinea Bissau	0.9	-
Indonesia	162.2	24,895 (1984)
Iran	45.2	3,104 (1985)
Iraq	15.7	1,486*** (1972)
Jordan	3.5	1,241 (1982)
Kuwait	1.7	1,511 (1984)
Lebanon	2.6(1983)	180 (1980)
Libya	3.6	1,100 (1980)
Malaysia	15.6	-
Maldives	0.17	-
Mali	7.5	-
Mauritania	1.7	-
Morocco	21.9	-
Niger	6.4	93 (1976)
Nigeria	99.7	2,200 (1977)
Oman	1.2	-
Pakistan	95	9,325 (1986)
Qatar	3.2	229 (1986)
Saudi Arabia	11.5	-
Senegal	6.6	522 (1972)
Sierra Leone	3.7	-
Somalia	5.4	-
Sudan	22	3,806 (1986)
Syria	10.5	-
Tunisia	7.1	-
Turkey	49.4	7,747 (1983)
Uganda	15.4	-
United Arab Emirates	1.4	-
Yemen A.R.	8	60 (1983)
Yemen P.D.R.	2.1	-
TOTAL		79,387

* From: *World Bank Atlas*, 1987.

** From: *UNESCO Statistical Yearbook*, 1987.

*** From: "Islamic Conference on Science and Technology", *Secretariat Report*, May 1983.

38

Science in the Third World

I am deeply honored by the award of the first Edinburgh Medal and the Prize. The Prize will go towards funding the Talent Fund for developing countries, which I had set up from the Nobel Prize. The Holy Prophet of Islam taught us to "thank men and women whenever they do good for you" – for "whosoever does not thank people, does not thank Allah." In keeping with this teaching I express my gratitude to you for kindly awarding me the Edinburgh Medal and Prize.

I came to the UK in October 1946 and my first port of call outside of Cambridge in December 1946 was Edinburgh where I was the guest of Professor Henry Jack, who was then taking the math tripos with me. Henry Jack was the biggest man I had ever seen in my life till that time. He was equally big and gracious in his hospitality. I fell in love with Edinburgh right away. Its fresh breezes seemed to course through the city – reminding me of the fresh breezes which coursed through my native town of Jhang.

Then Professor N. Kemmer, at Cambridge my supervisor for Ph.D., moved to Edinburgh leaving an empty place in Cambridge, which I was invited to fill in 1954. Kemmer had been an assistant of Professor Pauli and is very proud of it. Thus Edinburgh became a port of call for me once again. I remember the visit of Professor W. Pauli during 1957, when he was entertained for lunch by the Department of Physics. Pauli was a bit sleepy after lunch with the hospitality and the whiskey which had been showered upon him, but there was no getting away from Professor Kemmer, who asked his and my ex-student J.C. Polkinghorne to perform in front of Pauli and tell him what he had been doing on dispersion relations. Pauli had the status of an oracle in our subject. His word was law. But, just after a big Scottish lunch, it was a bit of a tall order for him to concentrate. So, when Professor Kemmer very sweetly, at the conclusion of Polkinghorne's presentation, asked Pauli what he thought about the subject, Pauli opened his eyes slowly and deliberately and said: "I pay no attention to dispersion-relations. I leave them to my present assistant." And that was all that one could get out of Pauli – the oracle – at that moment.

The next big occasion when Edinburgh was very much in my thoughts was during 1963-64 when I learned about the Higgs mechanism proposed by Professor Higgs. I learned it from Professor T. Kibble, who is also an Edinburgh graduate (Kibble is Head of the Department at Imperial College). Kibble taught

me about the Higgs mechanism which both Weinberg and I used to bring about spontaneous symmetry breaking in the unified electro weak theory, which got us the Nobel Prize.

This unification was couched in the same mould as the unification which was wrought by James Clerk Maxwell, a Scotsman and one of the greatest physicists the world has ever seen, concerning the relation of electromagnetism with radiation. Maxwell had shown that when a charged particle is accelerated, it radiates. He had found the speed of radiation to be equal to the ratio of electromagnetic to electrostatic charge. From this one number, which was measured carefully, and which was found to be nearly the same as the velocity of light, he went on to assert that electromagnetism and radiation are united. Maxwell died very young and did not live to see the great ideas being carried out in the laboratory to show that accelerating charges do produce radiation with the same velocity as that of light. But this unification remains one of the greatest landmarks in the whole of physics.

The Higgs Particle now forms the subject of even popular accounts of what to look for in the new generation of Particle Physics accelerators.

A humorous excerpt from an article by Peter Simple entitled "Quark Vader", which appeared in the London *Daily Telegraph* on April 27, 1988, was read out by D.H. Perkins at the 1988 Munich Conference: "American scientists are planning to erect the largest man-made structure in the world apart from the Great Wall of China. ... the scientists hope that this (the SSC) will prove one way or another their theory that almost everything that happens in the universe can be explained in terms of a cosmic struggle between two armies of particles, the quarks and the leptons. As yet, the theory has remained unproven because, as it is reported, 'for the sake of symmetry, the physicists have yet to find the sixth quark' and, most important, have had to introduce another particle, the Higgs particle, named after Peter Higgs of Edinburgh University. So, is the last riddle of the Universe about to be solved? Well, not entirely, because it turns out that 'the SCC will not be able to hunt directly for the Higgs particle' since this 'decays almost immediately' and furthermore some physicists 'like Chris Quigg hope they do not find it.' Just what is going on here? Who are the goodies and baddies in this story? Is Quigg the leader of the Leptons? Is Higgs himself the mysterious 'Sixth Quark', shadowy ruler of the universe? Will Quigg's leptons manage to overthrow Higg's evil empire before it is too late?"

The next occasion was in 1971 when Edinburgh University, at the instigation of Professor Kemmer, awarded me my first Honorary D.Sc. degree in very select company.

My thesis in speaking to a forum like this one is that the situation in the developing world is so bleak that without active involvement of the international scientific community it will not change. My thesis is that indigenous science in

the developing world is weak, but that it should expect and demand, as it were of right, fullest support from science abroad. We scientists pride ourselves as being the last of the idealists, our motives are not politically suspect, we fortunately possess a fund of goodwill through the work of the institutions which include private foundations, as well as the scientific agencies of the United Nations family.

The involvement of the world scientific community and the help it can give to the weak scientific communities in the developing countries can take many different forms. [...] ■

39

Maimonides' Scientific Contribution in Relation to the Milieu of Science in Islam

Abu 'Imran Musa ibn Maimun ibn 'Abdallah al-Qurtubi al-Isra'ili – often called *The Second Moses* or *the Moses of his time* – was a Hispano-Jewish philosopher, theologian, physician, mathematician and astronomer. He was born in Cordoba in 1135 AD, and died in Cairo in 1204. His family lived in Cordova until the Almohade conquest in 1148-49, when they left, and for a dozen years lived in various places in Spain; in 1160 they settled in Fez but were soon obliged to move again, reaching Fustat (old Cairo) in 1165. He spent the rest of his life in Cairo, as a famous physician. He was patronized by Salah al-Din's wazir, Al-Qadi al-Fail al-Baisani; later he became physician to Salah al-Din and to the latter's son.

Maimonides and Ibn Rushd were the greatest philosophers of their time. Neither knew Greek, and their knowledge of Greek philosophy and science was derived from Arabic translations.

Maimonides' most famous work was the *Dalalat al-Ha'irin*, or "Guide of the Perplexed", completed in 1187-90. "The design of his work," said the author, "is to promote the true understanding of the real spirit of the Law, to guide those religious persons who, adhering to the Torah, have studied philosophy and are embarrassed by the contradictions between the teachings of philosophy and the literal sense of the Torah." That is, Maimonides' purpose was to reconcile Jewish theology with Islamic Aristotelians, or faith with reason. To do this, he gave an allegorical interpretation of Biblical anthropomorphism, keeping clear at once of mysticism and of religious skepticism; for example, he explained prophetic visions as psychical experiences; and Jewish laws and customs from the point of view of comparative ethnology. He insisted that human perfection is inseparable from knowledge, and that the acquisition of knowledge is one of the highest forms of religion. To that extent Maimonides was the champion of science against Biblical "fundamentalism". In spite of its moderation, the *Dalalat* scandalized the more conservative theologians – they called it *Dalalat*, meaning error perdition.

It is of significance that all of his works except one (the commentary, *Mishneh Torah*) were written in Arabic, even if they were addressed to his fellow Jews. In answer to a contemporary request that he translate his work into

Reprinted from *Renaissance of Sciences in Islamic Countries*, by Muhammad Abdus Salam. Edited by H.R. Dalafi and M.H.A. Hassan, pp. 297-302. Singapore: World Scientific Publishing Co., 1994.

Spanish, he stated that it would thereby lose its specific character. When the rabbis of Lunel asked him to translate the *Guide* into Hebrew he stated that he wished he were young enough to do so.

Medicine

Maimonides' medical knowledge was derived mainly from Al-Razi, Ibn Sina, Ibn Wafid, and Ibn Zuhr; it was the standard Arabic Galenism of his time, but tempered with rational criticism based on direct observation.

Astronomy

We know some of his astronomical views through the *Dalalat*, which contains, for example, a discussion of Ibn Bahha's criticism of Ptolemy.

Maimonides rejected epicycles and eccentric movements as contrary to Aristotelian physics. However, such incompatibility of the models used by professional astronomers with the basic tenets of the Aristotelian world-view (Part II, Chapter 24, of the "Guide for the Perplexed") worried Maimonides. Thus while the epicycles and eccentrics employed by astronomers seem to violate the principle that the motion of the heavenly bodies be uniform, circular, and about a fixed center, he felt perplexed that the results achieved through the use of these very devices are startlingly precise. This, Maimonides says, is the "true perplexity".

Mathematics

Maimonides' major work in mathematics was his "Notes on Some of the Propositions of the Book of Conics". The existence of this text was first brought to the attention of the scholarly world by our colleague and friend, Dr. Fuat Sezgin, in volume five of his monumental *Geschichte des arabischen Schrifttums*. Since Dr. Sezgin is here I will not speak much about this except to say that the main aim of his treatise is to supply the missing steps to Apollonius' proofs, an endeavor which has occupied both ancient commentators such as Eutocius and modern ones such as van Eecke.

Maimonides' rationalist thinking and his reinterpretation of the Bible is evidenced by his remarks on the mathematically defined irrational nature of the diameter of the circle to its circumference. Maimonides writes: "You should know that the ratio of the diameter of a circle to its circumference is not known and it is never possible to speak of it truly. And the lack of this knowledge is not because of us ... but it is in the nature of this thing to be unknown and impossible to be reached. It can, however, be known approximately. The mathematicians have already written for it works to know the ratio of the diameter of the parameter approximately. The conventional way in this approximation on which the educated people rely is the ratio of one to three and one-seventh and every circle which has in its diameter a cubit will have in its parameter three cubits and one-seventh approximately. And since this will never be reached but approximately, they (the authors of the *Mishneh*), took the rough estimate and

said: 'Whichever has in its parameter three spans has in it a diameter one span.' And they relied on this estimate if one needs such a measurement in the Torah."

Astrology

In 1194, he addressed a letter to the rabbis of Marseilles, wherein he did not hesitate to condemn astrology in the most uncompromising manner. According to him, astrology is not a genuine science but a system of superstitions.

Forced Conversion

Many Jews had outwardly adopted Islam and their consciences were troubling them, and this prompted Maimun to write his *Iggeret Ha-Nehamah* ("Letter of Consolation") assuring them that he who says his prayers even in their shortest form and who does good works, remains a Jew. Although Maimonides most strongly deprecated the condemnation of the forced converts by "the self-styled sage who has never experienced in the way of persecution", his conclusion is that a Jew must leave the country where he is forced to transgress the divine law.

Rationalism

A discussion of Maimonides' rationalism is the more necessary because the subject has been obscured by many misunderstandings. To see it in its true perspective, one must remember that Maimonides was an ardent Aristotelian, and yet an orthodox and pious Jew.

Reason, Maimonides thought, being a gift of God, cannot be irreconcilable with religion. It must be possible to give a rational account of the universe without traversing religious dogmas, for both the world and the faith are from God. The main stumbling block was the Aristotelian theory of the eternity of matter. How could this be reconciled with the idea of creation? Maimonides' common sense revolted against the artificial doctrines of the Muslim atomists in this regard. He saw that one could not accept at once the eternity of matter and the account of Genesis; it was necessary to make a choice; he chose Genesis. This gives us a measure of his rationalism; he was ready to carry it to any extent compatible with his creed, but not further. What we would call natural law was for him design; all the regularities of nature are contingent upon the existence of a rational God. The world is one individual whole, rational through and through; for without rationality, there would not be any knowledge, or morality, or religion. He believed in the power of human thought to grasp metaphysical truth – and thereby laid the foundation of Jewish preoccupation with modern Science. Maimonides denounced vigorously the absurdities of superstition and was ever ready to uphold the supremacy of reason. In common with every other philosopher who was more inclined to rationalism than to mysticism, he emphasized the ethical side of religion; man must be good before he can be wise.

Conclusion

Maimonides was a true product of Arab-Islamic culture. In his courageous statement, "the gates of interpretation are not closed", he is even echoing a famous Islamic saying. But there was one special characteristic about his interpretations of Jewish scriptures. More than his near contemporary Ibn Rushd, he believed that Science too has its limitations, for Science continually changes and discovers newer syntheses. Whereas Ibn Rushd tried to justify what he thought was the scientific world view – Aristotle in his entirety – Maimonides rejected the ideas of Aristotle about eternal nature of matter. He took the attitude which we in science take today – there are matters on which Science, of its specialized nature, cannot pronounce. Thus Maimonides does not attempt to prove that the world was created in time. He is content to demonstrate that no proof for the eternity of the world exists.

It is harsh to say but I believe that it was Maimonides' humility in this regard which laid the foundation of Jewish preoccupation with modern science, while science in Islam died because Islamic Aristotelians could not bring themselves to repudiate what they thought were scientific pronouncements of Aristotle.

The conviction of Maimonides and his followers that divine revelation and philosophy agree in their ultimate nature was founded above all on their view that philosophy provided a confirmation and scientific proof of the monotheism of the Bible. Aristotle had demonstrated that all happenings in the world derived from a supreme divine principle. All movement and change of things had its cause in an Unmoved Mover, free from all corporeality, whose nature lay in His thought. In contrast to this, the Neo-platonic school derived also the existence of the world from God. The Arab Aristotelians incorporated this Neo-platonic conception into the Aristotelian system. They identified Aristotle's Unmoved Mover with the Neoplatonic One from which all Being of real things goes forth. Thus the Biblical belief in one God, to whom the Being of all things reverts, had been given its philosophical foundation.

While according to the teaching of the Bible the world has been brought into being by a free act of creation on the part of God, these systems view it as the necessary result of the ultimate divine Unity, from which the plurality of things stem in a continuous process. The contrast of the two attitudes is expressed in that difference that according to the Biblical belief in creation the world has a beginning in time, while in the Neoplatonic-Aristotelian theory eternal causation must correspond to the common ground with the Neoplatonists and the Arab Aristotelians. He demonstrates that this conception of God, too, does not lead to the deduction that the world must of necessity come forth from God. For this reason he is convinced that he does not deviate in principle from Aristotelian philosophy, but only frees it from certain deductions, which have no necessary connection with its basic character.

Each individual movement has come into being, but movement as such must be eternal.

Maimonides fully acknowledges this view as far as happenings within the world are concerned. But these laws apply only within the existing world. Nothing entitles us to ascribe to these laws of nature an absolute validity and to extend their application beyond the limits of the world. All that is denied is the validity of these laws outside the limits of nature as we know it.

As has been mentioned before, the Neoplatonists and following them the Arab Aristotelians endeavored to prove that the assumption of creation in time contradicts also the true conception of the nature of God. If any being, they said, begins an activity which it did not carry on previously, then a change takes place within that being, which must be due to some cause.

If the world had proceeded from God by logical necessity, then it should be possible to apprehend by logic alone why its structure is just so and not otherwise and why things follow upon each other in just that order. In reality, such logical consistency is absent even in the heavens, which according to that teaching arise directly from the spiritual world. The uppermost sphere, which is completely devoid of stars, is followed by a sphere bearing the entire mass of fixed stars; this in turn by the planetary spheres, each bearing only one star. The same lack of system and order is also evident in the movement of the celestial spheres, both with regard to their speeds and directions. If, therefore, the world has its origin in God, it cannot have arisen from Him with logical necessity, but must be the work of a divine act of will, which arranged the phenomena of nature in a manner not deducible by logic, in order to realize thereby certain aims. In our case, too, the irrational character of reality gives rise to the conclusion that the rise of the world from God cannot be understood as a logical process, but only as an act of will.

Historians of ideas think that *Dalalat al-Ha'irin* contains a very original thesis. In fact in his classification of concepts, Maimonides affirms that there are concepts which we can prove mathematically without being capable of conceiving them. He gave the example of the asymptote to an equilateral hyperbola.

The thesis is important: it shows that philosophers in the Islamic world were interested in the asymptotic behavior and positively (not only potentially) in infinite properties. The thesis of Maimonides was developed before him and in a more detailed and rigorous way by Muhammad bin Abdul Jalil Al-Sijzi, in his treatise on the "asymptote". Al-Sijzi classified the concepts used in mathematics as functions of two criteria: 1) the possibility or not to conceive them by the imagination, and 2) the possibility or not to prove them. This example shows that Maimonides was working completely in the rationalistic Islamic tradition. ■

40

A.D. Sakharov:
He Was a Legend in His Own Day

I met A.D. Sakharov only three times. The first occasion was at the 1974 Physics Conference in Moscow when he spoke on the subject of induced gravity — something he had been working on and which I liked very much.

The second occasion was in 1975 during the celebrations of the 250th Anniversary of the Academy. On this occasion, I had a long conversation with Sakharov who was very keen for my intercession with the rest of the Western delegation in order to get his ideas on Western thinking brought to bear when the problems of the Soviet Union were being considered. This meeting took place in the Kremlin where he (and I) attended a reception where Mr. Brezhnev was present. Sakharov offered to walk me down to the bus stop outside the Kremlin. We came down the two escalators and then outside to the bus stop.

On this occasion, many people accosted us coming down but no one had the courage to stop to talk with Sakharov. This I found amazing. It was quite clear that he was already a persona non grata (or was going to be officially soon, particularly after his exile to Gorky). I remember the number of physicists who I thought were sympathetic to his ideas but quite clearly they could not be seen with him in any intimate conversation. They wished us well from a distance and that was about all.

That night, I wished to convey a message to Sakharov and I rang up one of the physicists asking him for Sakharov's telephone number. He would not give me the telephone number of Sakharov, pretending that he had misplaced it. I understood his perturbation.

I sent a letter enclosing some of my papers to Sakharov while he was in exile at Gorky. These papers were returned to me with the statement of the Post Office, *Addressee not known*.

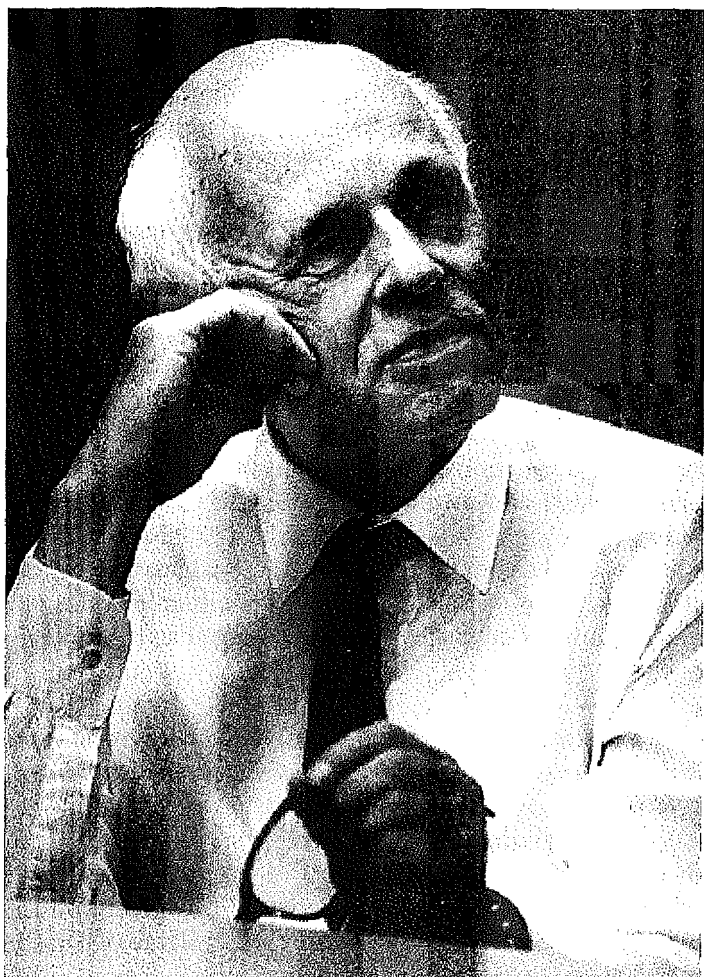
This was all very discouraging but then there was the triumphal return of Sakharov when Gorbachev came into power.

I saw him again, the last time, in February 1987 when I was attending the International Forum of Scientists devoted to the Problems of Drastic Reduction of Nuclear Weapons.

From *Andrei Sakharov, Facets of a Life*, ed. by P.N. Lebedev, pp. 577-78. Paris, France: Editions Frontiers, 1991.

I saw Sakharov after the Physics (private) seminar, which we had in A.D. Linde's office, which he attended. I was struck by his knowledge about all aspects of Physics. I thought it was a great thing for the subject in the Soviet Union that a man like him who was besieged by so many different things, could keep up in Physics so closely.

These are my recollections of Sakharov, the man and physicist whom I admired greatly. He was a legend in his own day. ■



55. Andrei D. Sakharov

41

Excerpts from *Science and Technology –
Challenge for the South*

1. Introduction

Progress in science and technology (S&T) has become the determining factor of the present, and, in particular, the future of mankind. This is generally recognized but, as yet, has only been expressed in words; the practical effects of S&T, according to J.D. Bernal, have yet to be fully appreciated and put into use. In the case of the majority of countries of the South, the situation is even worse since there is too little interest in S&T, which are paid only lip service. Such an attitude, unfortunately, dominates in the South in spite of the fact that science and technology is, undoubtedly, a major factor for its liberation from backwardness, poverty and exploitation.

Aware of this position, I have published several issues of the *Notes on Science, Technology and Science Education in the Development of the South* – whose writing was prompted by my work in a separate issue of the *Notes*. This facilitated detailed discussion and elaboration of S&T in the Commission's Report, which reflected the major points of the *Notes*, within the framework of overall development based on self-reliance of the South, individually and collectively. That was the first time that S&T had been dealt with in a report of such a type.

The *Notes* were distributed to scientists of the South – to members of the Third World Academy of Sciences (TWAS), the Third World Network of Scientific Organizations (TWNSO), and the Third World Organization for Women in Science.

Participants in the inaugural meeting of the TWNSO, attended by the representatives of thirty-six Third World countries, on learning of the work of the South Commission and receiving copies of the *Notes* at the Conference itself, adopted the following:

Chapters I, II, VII, XII and XIII of Abdus Salam's *Science and Technology: Challenge for the South* (Trieste, Italy: The Third World Academy of Sciences and The Third World Network of Scientific Organizations, 1992, pp. 1-10, 89-98, 163-68, 172, 173). The book was prepared at the request of Julius Nyerere, President of the South Commission, later President of South Centre, Geneva.

*Trieste Declaration on Science and Technology
as an instrument of development in the South*

Recognizing the fundamental importance of science in socio-economic and cultural development and technological progress, and keeping in view the recommendations of the South Commission¹ pertaining to the crucial role of science in the Third World, as mankind approaches the 21st century, the members of the Third World Network of Scientific Organizations present at the meeting held in Trieste from October 4-6, 1988, resolve to work towards giving Science and Technology a position of highest priority in their own countries and to strengthen their collaboration with other countries of the South as well as of the North.

The *Notes* were also distributed on specific occasions, such as the Ninth Summit of Non-aligned Countries, which gave support for S&T, including the creation of twenty new centers of excellence. Reaction to the *Notes* and statements on the issues included gave rise to the suggestions for more elaboration of some issues which, for the sake of conciseness I had omitted from the *Notes*.

In this present book, which I intend as a separate publication, considerable material from the *Notes* has been used, expanded quite extensively, and updated throughout, for example the chapter on science and technology. Certain chapters on items are completely new, in particular the chapters on contribution of S&T to economic growth, transfer of technology, and on the environment. The facts throughout are fully supported by figures.

¹The South commission was established in 1987 under the Chairmanship of Julius Nyerere, former President of Tanzania, following the years of informal discussions among intellectual and political leaders from the South. The Commission is made up of individuals from all the continents of the South, acting in their personal capacity. The Commission's work involved providing practical recommendations on strategies appropriate for and conducive to development of the South in the 90s and beyond, based on self-reliance.

As decided at its establishment, the Commission terminated its work after three years, in 1990, on the completion of its task by publishing its *Report*, "*The Challenge of the South*", distributed widely in many languages.

After the Commission Secretariat ceased operation, The South Centre in Geneva whose Advisory Committee is chaired by Julius Nyerere, continues to work as the follow-up office of the South Commission, cooperating with institutions of the developing countries and preparing papers on topics of major interest to them.

Underlying all the recommendations of the South Commission is the recognition, and clear statement, that responsibility for the South lies in the South itself, and in the peoples of the South, a sentiment echoed throughout this present book, and reflected in the title itself: *Science and Technology – Challenge for the South*.

This book deals with S&T in general. It covers results, achievements and shortcomings in the developed West and East, thereby pointing out challenges and offering opportunities for the South to take up. This stems in its entirety from my conviction that S&T are global in character and role.²

In dealing with the South, the countries that are developing, I am well aware that there are differences within this group of countries, as indeed there are within industrialized nations, though these latter exhibit slighter distinctions. Examples showing notable differences are East and partly South Asia, the Middle East, the traditionally more developed countries primarily in Latin America, faced with a slow-down, and finally the least developed countries, with a special case of sub-Sahara Africa. An attempt has been made to present specific examples within various DC (Developing Countries) sub-groups, as well as global data on these nations, depending of course on the availability of sources of statistics. Comments are included wherever helpful.

In the context of the differences referred to above, may I quote the statement of the South Commission: "Yet in this diversity there is basic unity. What the countries of the South have in common transcends their differences; it gives them a shared identity and a reason to work for common objectives. And their economic diversity offers opportunities for cooperation that can benefit them all."

I hope it is clearly understood that commendations (or condemnations) of experience in various countries such as Australia, Bangladesh, Brazil, India, Pakistan, South Korea, Singapore, South Africa, UK, USA, the former USSR, or Venezuela, interspersed throughout, are directed only at their science policies and do not make any reference to their political systems.

I wish to acknowledge Julius Nyerere, President of the former South Commission and fellow members, for incorporating science and technology into its program, and for arranging during its work very stimulating and penetrating discussions, the findings of which were incorporated into *The Report of the South Commission – The Challenge of the South*.

I am indebted to colleagues of mine present at the inaugural meeting of the Third World Network of Scientific Organizations held in Trieste from October 4-6, 1988 for adopting the *Trieste Declaration*, presented in the Introduction, as indeed I am to my fellow members of the Third World Academy of Sciences for their support of my work in the South Commission, their constructive comments and interest in the published "*Notes on Science, Technology and Science Education in the Development of the South*", and for inspiring the Third General Conference of the Third World Academy of Sciences and the Second General Meeting of the Third World Academy of Scientific Organizations, held in Cracas in 1990.

One of my fellow Commissioners, Augustin Papic, with whom I began an enduring and rewarding collaboration in the South Commission, deserves credit for encouraging me to write this extension through his continual persistence and in actually rewriting some part of the book himself.

The issues covered in this book were partly dealt with in an international conference "*The Essential Role of Science in Technological Progress and Economic Development*." The conference was convened by myself and Louis Emmerij, Director of the OECD Development Centre, Paris, at the Adriatic Guesthouse of the ICTP, Trieste, Italy, from April 22-24, 1992.

II. *Science and Technology – A Shared Heritage of Mankind*

II.1 *Science and Technology are Cyclical*

The first thing to realize about the S&T gap between the South and the North is that it is of relatively recent origin. In respect of sciences, George Sarton,³ in his monumental *History of Science*, chose to divide this story of achievement into Ages, each Age lasting half a century. With each half-century, he associated one central figure. Thus the years 450-400 BC Sarton calls the Age of Plato; this is followed by the half-century of Aristotle, of Euclid, of Archimedes, and so on. These were scientists from the Greek Commonwealth consisting (in addition to the Greeks) of Egyptians, Southern Italians and ancestors of modern Turks and Syrians.

From 600 AD to 650 AD in Sarton's account is the Chinese half-century of Hsüan-tsang. From 650 to 700 AD is the age of I-Ching and of the Indian mathematician, Brahmagupta, followed by the Ages of Jabir, Khwarizmi and Razi, Masudi, Wafa, Biruni, and then Omar Khayyam – Chinese, Hindus, Arabs, Persians, Turks and Afghans – an unbroken Third World succession for five hundred years. After the year 1100, the first western names begin to appear: Gerard of Cremona, Roger Bacon, and others – but the honors are shared for another two hundred and fifty years with the Third World men of science like Ibn Rushd, Naseer-ud-din Tusi, Musa ibn Maimun and Sultan Ulugh Beg.

The same story repeats itself in technology. In China, the Chinese had invented the technology of printing on paper, gunpowder and the magnetic compass. In the Middle East, till around 1450, the Turks captured Constantinople because of their mastery of superior discipline and cannonade. No Sarton has yet chronicled the history of medical and technological creativity in Africa – for example of early iron-smelting in Central Africa 2,500 years ago,⁴ nor of the pre-Spanish Mayas and Aztecs – with their independent invention of the zero and of the calendars, of the moon and Venus, as well as of their diverse pharmacological discoveries, including quinine. But one may be sure, it is a story of fair achievement in manufacturing technologies and applied sciences.

From around 1450, however, the Third World began to lose out, except for the occasional flash of individual brilliant scientific and technological work –

³ George Sarton, 1927. *Introduction to the History of Science*, 5 volumes. Washington DC: Carnegie Institute, reprinted 1962.

⁴ *Scientific American*, June 1988.

principally because of the lack of tolerant attitudes towards the creation of sciences and of technology. "It is good to recall that three centuries ago, around the year 1660, two of the greatest monuments of modern history were erected, one in the North and one in the South; St. Paul's Cathedral in London and the Taj Mahal in Agra. Between them, the two symbolize perhaps better than words can describe, the comparative level of architectural technology, the comparative level of craftsmanship and the comparative level of affluence and sophistication the two cultures had attained at that epoch of history. But about the same time, there was also created – and this time only in the Northwest – a third monument, a monument still greater in its eventual import for humanity. This was Newton's *Principia*, published in 1687. Newton's work had no counterpart in the India of the Mughals."⁵ It was not reported on by Jesuit priests who had been commissioned by one of the successors of Shadyan, the creator of the Taj Mahal in Agra, to bring back from Europe whatever was new and exciting in astronomy.

And that brings us to the present times when the cycle begun by Michael the Scot who went from his native glens in Scotland, around the year 1220 AD, south to Toledo and then to Sicily in order to acquire knowledge of the works of Razi and Avicenna – and even of Aristotle (the only available translations then being in Arabic) – turns full cycle – and it is we in the developing world who must turn northwards for sciences.

The revolutionary science of the Renaissance distinguished four major periods of advance in its development. The first, centered in Italy, produced the renewal of mechanics, anatomy, and astronomy with Leonardo, Vesalius, and Copernicus, destroying the authority of the Ancients in their central doctrines of man and the world. The second, spreading to the Low Countries, France, and Britain, beginning with Bacon, Galileo, and Descartes, and ending in Newton, hammered out a new mathematical-mechanical model of the world. After an interval, the third transformation, centered in industrial Britain and revolutionary Paris, opened up to science areas of experience, such as that of electricity, untouched by the Greeks. It was then that science was able to help in a decisive way with power, machinery, and chemicals, to transform production and transport. The fourth and greatest of all in extent and effect is the scientific revolution of our own time. We are witnessing the beginning of a world science, transforming old and creating new industries, permeating every aspect of human life. It is now also, during this period of transition, that we find science directly involved in the violent and terrible drama of wars and social revolution.⁶

⁵ Abdus Salam. 1989. *Ideals and Realities*, 3rd edition. Singapore: World Scientific Publishing Co., pp. 5-6.

⁶ J.D. Bernal. 1986. *Science in History*, Vol. 1. Cambridge, Massachusetts: MIT Press.

Science and technology are cyclical. They are a shared heritage of all mankind. Northeast and northwest, southeast and southwest have all participated in their creation and application in the past, the joint endeavor in sciences becoming one of the unifying forces among the diverse peoples on this globe.

There is no guarantee that the Northwest will always have a monopoly on S&T. There are already indications that China, some East European and Asian countries, India and Brazil, because of their superior qualities, may acquire it, if they wish to.

II.2 Benefits, but also Risks, for Mankind

A. The double-edged sword

S&T have brought great benefits to mankind, but they contain risks. That is why V. Weisskopf called technology the double-edged sword. Weisskopf spoke on the positive and negative side of technology. On the positive side could be counted achievements in economic growth and its components, social benefits, many achievements in food supply including the green revolution, medical sciences, humanization of the capitalistic industrial system (eradicating hunger, want, illness and oppressive manual work).

B. The quality of human life

People's living conditions, such as food supply, health, education, adult literacy and life expectancy have improved in part through S&T.

a) The green revolution contributed to a considerable improvement in daily calorie supply, which grew in the two decades between 1965 and 1985 (as a percentage of requirements) in the cases of:

- all developing countries from ninety to one hundred and seven, but sub-Saharan Africa declined from ninety-two to ninety-one;
- industrial countries registered an increase from one hundred and twenty-four to one hundred and thirty-two, the world average growing from one hundred to one hundred and thirteen.⁷

Owing to the green revolution in the first part of the 1980s, the world lived with a surplus of food but still, due to inequalities and other economic deficiencies in this field, a great number of men, women and children, particularly in the South, were not receiving enough calories in order to support an active life. So food security remains at the head of the agenda for mankind, particularly in such regions as sub-Saharan Africa.

In the field of food and agriculture, we have faced two challenges: one is the risk to the human environment due to the negative implications of artificial fertilizers and pesticides. Thus the ascendancy of studies and trends for chemical

⁷ UNDP. 1991. *Human Development Report 1991*. London: Oxford University Press.

free farming. Recently a decision was announced to ban the use of fifty-seven registered pesticides in Indonesia rice fields.⁸

Another challenge is the fact that the impact of the green revolution on agricultural advancement has almost run its course, particularly in Asia and Africa. Increasing concerns have been expressed about coming food shortages resulting from the fact that success in food production has come about at the expense of soil and water resources, falling water tables, declining cultivated green areas, lower yields and, in particular, prospects for climatic changes due to greenhouse gases. New technologies are now required (though according to some, we face a dwindling backlog of technology), and opportunities have been explored for the second green revolution.⁹

b) Food and health improvements contributed to an increase in life expectancy: in thirty years (1960 to 1990) for all developing countries, on average from 46.2 to 62.8 years, while sub-Saharan Africa, though improved, was still behind that average (51.8 years in 1990). Life expectancy in the industrial countries grew from sixty-nine to seventy-four in the above period.¹⁰

c) Between 1970 and 1990, the adult literacy rate improved in all developing countries regions, with an average from 46% to 64%.

d) However, because of social and economic inequalities and deficiencies of international economic relations, the above achievements are not shared by all and poverty dominates in a large part of the South. The number of extremely poor in 1985 amounted to 1,740 million, and 54% of the population in the South was below the poverty line. In sub-Saharan Africa, that percentage was 77%.¹¹ The poverty was a source of many other shortcomings the South was suffering. The degradation of the human environment has been one of them, since poverty forces people to an over-exploitation of natural resources.

e) The improvement in social and human conditions pushed the population growth up. Between 1960 and 1990 (in thirty years), the population of the South increased by 97%, from 2,070 to 4,070 million, while that of the industrialized countries grew only by 27%. Because of the above trends, the share of the South

⁸ United Nations. 1990. *24 Development Forum*. New York: UN Department for Public Information. (September/October).

⁹ The World Watch Institute. *State of the World 1988*. Washington DC: Worldwatch Institute. Quoted Lester Brown, President of the Institute: "World food prospects: bad getting worse", *International Herald Tribune*, July 4, 1988. On the second green revolution, see Nadir-Azam Ali, *Beyond the Green Revolution in Pakistan*, Appendix XXVI, p. 252. On the subject of food security in the South, may I call attention to the chapter "Agricultural development and food security" presented in *Challenge to the South*, Report of the South Commission, Oxford University Press, 1990, pp. 83-91.

¹⁰ UNDP. 1990 and 1992. *Human Development Report, 1990 and 1992*. London: Oxford University Press.

¹¹ World Bank, 1990. *World Development Report 1990*. London: Oxford University Press.

in the world population increased from 68.5% in 1960 to more than three-quarters (77%).

We are confronted with a population explosion in the immediate future (6,250 million in the year 2000).¹² That would put great pressure on all natural resources, pushing migration and population movements from poor to richer countries, etc. Science has invented the means for control of population growth (contraceptive pill) but that control depends greatly on political and social thinking, particularly religious conditions in countries, which frequently limit the effect of the control. [...]

C. S&T source of risks and damages

Weisskopf emphasized that during the last twenty years the values underlying development of S&T have frequently been called into question.¹³ That was the case particularly in the 1980s, when a succession of high-tech disasters were registered and received great publicity.¹⁴

Scientists have been well aware of the risks and hazards as a negative side of their discoveries, and they normally make efforts to minimize and, if possible, to eliminate these. However, as experience has demonstrated, in many cases politicians and economists ignore the advice of scientists in order to save money or to build up projects quickly. In the case of the Chernobyl disaster, it was stated that "before Chernobyl, people who were responsible for the development of nuclear energy said that economic reasons were more important than scientific ones".¹⁵ Similarly, the decision-makers in business neglect, and sometimes ignore, the position and advice of scientists because they are motivated by quick profit.

VII. Transfer of Technology

VII.1 Domestic R&D and Imports of Foreign Technology

No country can opt for creation and diffusion of domestically produced technology without the import and diffusion of a foreign one. At the same time,

¹² UNDP, 1990 and 1992. *Human Development Report, 1990 and 1992*. London: Oxford University Press.

¹³ Victor F. Weisskopf. 1989. *The Privilege of being a Physicist*. New York: W.M. Freeman and Company.

¹⁴ Chernobyl nuclear power plant catastrophe; Union Carbide's Bhopal pesticides tragedy; the Sandoz and Ciba-Geigy Rhine River chemical spills; the radiation disaster at the medical clinic in Goiania, Brazil; the Asland Oil tank collapse near Pittsburgh. See: *The Hard Technology Path - A Brief History of the March of Progress of New Technologies. Development Dialogue: The Law of Life*, Vols. 1-2, 1988.

¹⁵ Yri Ossipyan, USSR, at the forum on "Science and Government", held in December 1989, at the Weizmann Institute of Science in Israel. Quoted in *New Scientist*, March 10, 1990.

an efficient transfer of foreign technology¹⁶ and thus stable technological development cannot be productive unless accompanied by a reasonably high level of domestic R&D.

The characteristics of importing technology should be taken into consideration when defining R&D priorities, while the capability in the latter field should influence the import of technology. To rely only on domestically produced technology is not rational or feasible, while to concentrate mainly on import and diffusion of foreign technology leads to technological dependence. Therefore, an adequate balance between them, both on a sectoral and global basis, should be achieved, taking into account specific conditions of individual countries.

A recent OECD study¹⁷ dealt with the above aspects of technological development of OECD countries coming to the data on relationship between R&D, technological balance of payments (TBP) and imports of high technology products as presented in the Table on the following page.

Without entering into details, a few points can be emphasized:

- The unique position of the USA as the country with a very high share of R&D and a low share of imports of high-tech products.
- In other major ICs like Germany, Japan and the UK, imports of high-tech products amounted to around half the investment in technological development. Surprisingly, Greece belongs to this group.
- Spain, whose situation is considered separately in the source publication mentioned in the Table, showed a very unbalanced situation, where too many sources have been devoted to importing foreign technology (high TBP payments and high imports of high technology products) with rather low R&D share. The case of Spain may also apply to many less ICs, though data are not available.
- The position of Portugal is worse, particularly with regard to R&D achievements and very high percentage of import of high-tech products. It is for this reason still closer to the smaller DCs.

¹⁶ However, it is a one-sided approach if the transfer of science is omitted, which complements transfer of technology. This transfer is very different from that of technology. It is freer, through scientific literature, participation in foreign or international research activities, universities, various scientific meetings, etc.

¹⁷ The inter-relation between R&D and technology imports. The situation in some OECD countries. *STI Review (OECD)*, April 9, 1992.

Selected investments for Technological Development (%)

		R&D ^a	TBP Payments	Imports of high-tech products ^b
France	(1985)	47.2	4.3	48.5
	(1986)	50.6	4.2	45.2
Germany	(1985)	43.1	3.1	53.7
	(1986)	43.1	3.5	53.4
Greece	(1985)	50.5	3.6	45.8
	(1986)	47.9	3.7	48.1
Italy	(1985)	42.0	4.8	53.2
	(1986)	44.0	4.6	51.4
Japan	(1985)	48.2	1.6	50.2
	(1986)	49.4	1.4	49.2
Netherlands	(1985)	28.6	7.5	63.9
	(1986)	30.0	7.2 ^c	62.7
Portugal	(1985)	11.2 ^d	5.6	83.1
	(1986)	17.6	5.0	77.4
Spain	(1985)	28.6	19.9	51.5
	(1986)	32.8	18.1	49.1
United Kingdom	(1985)	45.0	3.0	52.0
	(1986)	45.3	3.1	51.6
United States	(1985)	70.5	4.0	25.5
	(1986)	69.4	4.2	26.3

Key. a) OECD. Gross domestic expenditures on R&D. Main Science and Technology Indicators, 1982-88. b) OECD. Trade Statistics, 1974-86. c) 1985 data. d) 1984 data. Source: The interpretation between R&D and technology imports. The situation in some OECD countries. *STI Review*, April 9, 1992.

VII.2 Imported and Domestic S&T Capabilities

Besides data presented in the section above, an additional justification for the role of transfer of technology could be found in the cases of most successful DCs in their scientific and technological development. As illustrated in the following Annexed Table VII.2A, DCs of Asia, otherwise successful in domestic scientific and technological development, became a major importer of capital goods and foreign direct investment, which implies imports of foreign technology. At the same time, the share of developing America increased very modestly, while the share of developing Africa in the case of capital goods decreased but increased in foreign direct investment.

We can see that inflow – imports of capital goods of Asia – increased from 49.6% to 61.9% of that of all DCs. At the same time these countries were able to increase their share of export of capital goods of all DCs due to strengthening of domestic scientific and technological capabilities, from 15.8% in 1980 to 50% in

1989. Also, the share of these countries in foreign direct investment of all DCs increased from 18.2% to 53.1%.

The case of China is very illustrative, its imports of foreign capital goods, including technology, tripling in nine years (between 1980-89). The case is similar for foreign direct investment which, in the above period, increased thirty-four times, that is from 0.1 to 3.4 billion dollars.

All the above indicates that countries with adequate educational, scientific and technological bases, were most successful in imports of foreign technology, its absorption and utilization, thus strengthening their scientific and technological capacity, which was illustrated by the considerably high export of capital goods and increase in foreign direct investment. [...]

VII.3 Accelerated Pace of Technological Change – Impact on Transfer

A. The pace of technological change has accelerated rapidly in the last two decades. Led by major ICs and transnational corporations, it contributed to the widening gap with the South. This relates not only to the field of technology, but also to the overall position in the world economy, eroding their competitive position due to cuts in the consumption of raw materials (natural first of all), decline in their prices, and the decline in the role of the labor force – as factors of production abundant in many countries of the South.

B. The above development made transfer of technology, first of all science-based high technology, which is knowledge-intensive and research-intensive, with the rate of technological obsolescence tending to be very high, desirable but very complex for the DCs. The growing costs of R&D and the desire to protect innovations from imitation, the interest to maximize gains from the exploitation of new technologies induced intellectual property-rights protection through GATT negotiations, mergers, joint ventures and various types of strategic technical alliances. The above relates basically to three technological fields: electronics and informatics, biotechnology and genetics, and new materials.

There have been trends towards increasing privatization, transnationalization and strengthening of technological monopolies. In the 1990s trends are expected that hinder access and increase the costs of new technologies, through royalty payments on know-how, patents, higher licensing payments in patent-intensive industries. The above relates especially to the sectors of pharmaceuticals, chemicals, semiconductors and computer industries.¹⁸ [...]

¹⁸ UN Centre on TNC. 1990. *Transnational Corporations and the Transfer of New and Emerging Technologies to Developing Countries*. New York: United Nations.

VII.5 Risks of DCs in the Choice of Imported Technology

A. The essential factor of sustainable growth and efficient industrialization is technological dynamism, which can be defined as the ability of a country to absorb and efficiently deploy new technologies, adapt them to local conditions, improve and disseminate them, and ultimately create new knowledge, including their own scientific and technological base.

The final aim of all of the above, the absorption of technologies could be broadly measured by the capacity to employ new processes, to produce new goods and services, in a more efficient way than before.

B. As a precondition to the above, including the transfer of technology the success cases indicate the availability of domestic educational basis, human resources, and at least initial steps in the domestic scientific foundations, required institutions, enterprises capabilities and incentives. The importance of the latter can be best illustrated by the cases of DCs of East Asia and failure of many other DCs, including countries of Eastern Europe.

C. However, there is risk in choice of capital goods, machinery and equipment, that suits best the needs of the importing country. Many failures were registered in this respect. That is especially true in the case of turn key projects, where complete factories are bought from abroad, assembled and put into operation. That type of arrangement is made by countries of the South without experience and ability to build by themselves such factories, and especially in the case of newly-developed technologies. All is made by consulting and engineering firms from abroad, closely connected with the exporters of capital goods, securing the profits for all foreign partners, while imposing not rarely failures on the DCs concerned. Among many cases, the example of Togo can be taken as an illustration of a country being raped by foreign interest through the use of unsuitable technologies.¹⁹

Other problems include financing and pricing of imported capital goods which are used by the exporter for additional profits.

D. Foreign direct investment (FDI) though much lesser volume than capital goods imports, in their financial scheme include technology transfer, management, marketing. Here the importing DCs are exposed to much higher risks since the foreign partner has a more decisive role in the choice of technology, its pricing, financing and export/import, which normally follows such arrangements.

The transfer pricing is a widely applied form of the exploitation by foreign direct investment (FDI). Since the FDI mostly include mutual deliveries of goods

¹⁹ The case of Togo, which was a victim of unscrupulous foreign investors: over-optimistic market "studies", no competitive bidding in the case of Togo's plastic industry, a corrugated-iron roof factory and a steel mill, which were all failures. (*IFDA Dossier*, 71, May/June 1989.)

and services, higher prices are charged to the deliveries from foreign investors to their partners in the DCs, and lower prices for the purchases from the latter – all compared to competitive world prices.²⁰

All this means losses of income and profit for the partners in the host countries, mainly developing, but as published recently, also in the USA.²¹

Foreign direct investor, particularly transnational corporations used to impose various limitations on their partners in the recipient countries. For example, limitations in the production of components of products by their partners in DCs;²² limitation on export of goods or services to markets of interest for foreign partners; limitation of cooperation of affiliate or joint venture with other domestic producer in recipient countries in order to hold market monopoly.

E. Acquisition of licenses and patents is the easiest way to buy intellectual property rights for the technologies available at the international market. Many DCs are flooded with foreign licenses or patents (even for the same technology). Few of them are ever applied, since this is the most complicated way of introducing new technologies into production of goods and services.

²⁰ Overpricing by large pharmaceutical firms on components delivered to Latin American countries moved between 33% and 313.8%. In the case of electrical goods it rose from 24.1% to 81.1%. See: UNCTAD: *Dominant Position of Market Power of Transnational Corporation*, 1978.

On the export side from Latin America, lower prices were paid by their foreign partners amounting to an outflow of resources of US \$427.5 million of 40% on average. See: G. Bergsten: An analysis of US foreign direct investment policy and economic development. *Aid Discussion Paper*, No. 36, November 1976.

The underpricing of timber occurs in the Pacific island countries through a method of undermeasurement, or by misdirection of species or grades. In two African countries, the transfer pricing is made in the context of the processing, smelting and refining of mining products. The problem lay in the level of fees charged for the tolling operation, and the level of income tax paid by foreign companies, which depends on that price. See UN Commission on Transnational Corporations: *Transnational Corporations in World Development*, New York, 1988.

²¹ It is estimated in the USA that foreign-based companies sold goods in 1986 worth US \$543 billion but claimed to have net losses of US \$1.5 billion. This is the result of abuses made in cross-border transfer pricing by foreign companies which represented a tax loss for the USA of between US \$20 and US \$30 billion. Even US multinationals were accused of squirreling profits away to their foreign affiliates, amounting to an additional US \$5 billion in lost taxes on profits. See: *Newsweek*, April 15, 1991.

²² This can be illustrated by the attitude of Japanese investors in Indonesia. "Tokyo is Jakarta's most important trading partner, biggest investor and most generous aid donor. But, in Indonesia, Toyota has allowed the local company P.T. Astra International Inc. to produce only a few automotive components; for the most part it's an assembly-line production putting together parts from Japanese kits." See: *Newsweek*, October 14, 1991.

VII.6 Appropriateness of Transferred Technology

Perhaps it is worthwhile quoting here the discussion at a seminar on transfer of technology held in Kuala Lumpur.²³ The general consensus at the workshop was that most of the transferred technology was inappropriate. In most cases, R&D is located in the home countries of TNCs (Transnational Corporations), and not enough technology is transferred. In addition, TNCs do not conduct appropriate training programs in host countries, which would allow them to benefit from this transfer. However, TNCs are in a position to play a useful role through adaptation of their technology to developing-country conditions. They can incorporate training programs appropriate to the conditions of the host country into their activities. In addition, they could be required to include a minimum of local content in their production activities or to take into account the demands dictated by "choice of product" rather than only those prescribed by the logic of "choice of techniques".

Finally, let me mention the Resolution "Transfer and Development of Technology" adopted at the thirty-eighth session of the Trade and Development Board of UNCTAD, held in Geneva, April 22-30, 1991, quoting one among several paragraphs: "Calls upon governments to adopt measures, including intellectual property rights protection and technical cooperation, to increase technology flows to DCs and facilitate their access to technology, in particular those new and advanced technologies of critical importance for their development, with a view to reducing the existing technological gap between industrialized and DCs; recognizes that in this regard states, as an aspect of national sovereignty, will take into account their public interest and development objectives and further recognizes that export restrictions can impede technology flow."²⁴

XII. A Blueprint for S&T for the Developing World

XII.1 Science and Technology Policies for Developing Countries

If one were charged with running S&T in a typical developing country of modest size, one would, in the first place:

- Make sure that the high-level scientists and technologists in any given country know exactly what is expected of them. Their work for development

²³ Patric A. Muma. TNCs and economic development. An article based on the discussion at the seminar on Transnational Corporations and Economic Development, January 11-29, 1988, University of Malaysia in Kuala Lumpur, held for participants from different ESCAP countries. The seminar was organized by the UN Centre on TNC. See: *The CTC Reporter*, 31, Spring 1991.

²⁴ *Report of the Committee on Transfer of Technology on its Eighth Session*, April 22-30, 1991, New York.

should be looked after by the highest possible authorities in the land – if possible, by the rulers themselves. (Every country has a set of Merlins within their scientific communities capable of working, or at least supervising miracles. However small their numbers may be, these men and women must have their morale built up. They must get the scientific infrastructure plus the equipment plus international contacts they need to carry through their work. Reciprocally, they have to be told that they cannot afford to live in their ivory towers, that they must make themselves available to the developing public and that society will expect returns from them.)

- Carry through the recommendations in respect of general science education, in particular at secondary level.
- Build up at the same time expertise in classical low technologies emphasizing craftsmanship and fabrication.
- One would import some of the technologies from abroad, taking care, however, that every importation is supplemented by indigenous training.
- Build up as a matter of priority comprehensive technological information centers.
- One would commission and blue-print a comprehensive plan for applied sciences and for high technology. What one develops first, depends upon a nation's priorities and could be in one or more of the following areas: agriculture (in particular, the promise of discovering and utilizing newer species of plants),²⁵ livestock, health, population, energy, local materials and minerals, environment, soil sciences and seismology, atmosphere and oceans, biotechnology, informatics (microelectronics and microphotonics) plus new materials.

²⁵ "A new orientation of Third World agricultural activities is needed. Up to now, agriculture has been dependent on very few crops that have been developed by the advanced societies. The same applies to the agricultural systems. As an example one must remember that in the tropics, there are more than three thousand species of which very few are actually used and nothing is even known about their potentialities for food and forage.

"In Venezuela in the tropical arid regions, it has been found that the pods of a native species (*Prosopis juliflora*) contain around 18% protein and some experiments have shown that its flour or meal can be added to bread or cookies, thus obtaining a protein enriched product from a tree that up to now has not been thought of in this context.

"Studies on *Aloe vera* (a plant used in medical industries) have, for example, shown that it grows much better under the shade of trees than in the open and thus the combination of *Prosopis* and *Aloe* as a field system will yield a much better productivity than the planting of traditional crops under water limiting conditions. Just by planting *Aloe*, cotton or bean under the shade of trees, around 30-40% of the water needed for irrigation is saved.

"There is the urgent need for research to be oriented to find out what should be used among the thousands of species of both plants and animals in the tropics"

– Miriam Diaz, CIEZA, Venezuela

- One would build up scientific and technological research within the universities. For this purpose, one would institute training programs (within the country and abroad), for cadres of scientists and technicians so as to assure critical sizes of local communities.

XII. 2 *Expenditures on Basic and Applied Sciences and on Low and High Technology*

On basic plus applied sciences plus science-based high technology, one would need to spend a minimum of 4% plus 4% plus 8% = 16% of the educational budget respectively.²⁶

What should be spent on training, development and research in the classical low technology area? The short answer is as much as one may afford.

One minimal figure, which has been suggested is worth repeating. It is UNESCO's famous 1% of GNP for all sciences ("basic" and "applied") plus all technology (classical as well as high). On the average basis of 4% of GNP being spent on education by the South (with 16% of this for science and high technology), this roughly works out at 1/6:1/6:1/3:1/3 of 1% of GNP for "basic" and "applied" sciences versus classical low technology versus high technology.

XII. 3 *Initial Training*

Where would one get the necessary initial training? Clearly, here, one would have to rely on the universities and the institutes in the North (or on South-South collaborative programs) or on the United Nations centers for providing the training facilities.

A. *Training in basic sciences.* For basic sciences, there are ICTP, ICGEB, and ICS, for physics, genetic engineering and biotechnology, chemistry, the environment, high technology, new materials, run by the IAEA, UNESCO, and UNIDO, or else the International Centre for Insect Physiology and Ecology (ICIPE) in Kenya.

B. *Training in applied sciences.* For applied sciences – for example, agriculture – one would think of international centers comprising the CGIAR Network, with enhanced training components. There are three centers devoted to research on tropical agriculture (in Colombia, India and Nigeria, a fourth in Syria) concentrating on agriculture in arid zones, a fifth (in the Philippines) on cross-breeding of rice, and three on genetic improvement of cattle (in Ethiopia,

²⁶ Annexed Table V.5A [see p. 187 in the Salam book] shows the desirable minimum to be spent on science and science-based high technology as 15% rather than 16% of the educational budgets. This has been done deliberately in order to make it possible to carry through the program of S&T enhancement in five years with 3% increase of the educational budget every year. I strongly believe that a uniform 3% increase per year for the next five years in the educational expenditures will not break these countries' finances.

Kenya and the Ivory Coast), plus the International Center for the Potato (in Peru). In addition, there is the Centre (in Rome) for the conservation of genetic resources, one (in Holland) for the fostering of rural agricultural cooperation, a twelfth in Washington DC for the study of nutrition, and, finally, the world-famous Wheat Institute (CIMMYT) in Mexico.

This group of thirteen institutes commands a total of US \$250 million collected from donor countries by the World Bank. Hope and expectation is also placed in the twenty centers for research and training in science, high technology and the earth's environment – particularly in Africa – needing a similar measure of funding by the World Bank and other donor governments. (It is important to realize that the CGIAR institutes, emphasizing inputs of pesticides, insecticides and fertilizers, represent the discipline of chemistry, which, in this sense, is a survival science. Once physics and high technology are emphasized also by the World Bank – in the proposed network – one will be moving on to sciences that are wealth-producing. It is this type of altered perception of the Third World that we desperately need.

XII. 4 *Special Points for Consideration*

There are a number of special points, which should be remembered in connection with the application of S&T to development:

- one must remember what was said regarding the long-term nature of S&T as applied to development. We are not likely to see the benefits for a long time. The year 2000 would be a good year to aim at if we start today.
- We have stressed the necessity for saving on armaments and defense expenditures, at least for the South – 10% of the present defense budgets – and expending the funds thus saved for enhancement of S&T.

XIII. *Envoi*

In this book, I have pleaded that political action is needed both by the South and the North, in order to build up the morale and to utilize the so-far neglected community of the South's own scientists and technologists. Their numbers need to be multiplied so that they come to constitute a critical size; they have to be given proper recognition, provided with scientific literature and comprehensive technological information as well as the requisite infrastructure for research and development plus the international contacts, principally by those who run our countries. This community of scientists and technologists may be ill-prepared at present for taking on the developmental role but with careful nurturing and proper trust, they surely have the capability of transforming the South. As their colleagues have done in the North.²⁷

²⁷ I have been wondering why Europe should be uniformly good at S&T. Even a country as little known for scientific achievement as Bulgaria can produce first-class mathematicians and theoretical physicists if it puts its mind to it. (This is evidenced by the Bulgarian scientists who come to the ICTP). It seems to me the answer lies in that one

There is no question but that our present world is a creation of modern science in application. We tend to forget that it was the science of physics in application, which brought about the modern communications revolution and gave a real meaning to the concept of One World and its mutual interdependence. We tend to forget that it was the science of medicine, which brought about the penicillin revolution, leading to the present level of world population. We tend to forget that it were the sciences of chemistry and genetics in application, which brought about the fertilizers and the green revolutions, to feed part of this population. And we tend to forget that it is to these same sciences – the wealth-producing sciences of physics and geophysics, together with the (survival) sciences of medicine, molecular biology, cell culture and chemistry – to which the Third World has to turn (and is turning) for resolution of some of its current problems.

Judging from the actual versus desirable levels of educational and science expenditures, it is clear that while Latin American as well as the Confucian-Belt and other Asian countries are indeed taking steps to enhance their scientific and technological communities, the African, the Arab, and the Islamic countries by and large have a long leeway to make up. There appears scant future for S&T in these societies at present, particularly if the tryst with the year 2000 is to be kept.

must treat all of Europe as a single cultural entity. If one member of the cultural entity is good in sciences, it seems that all members of the same cultural unit can be, if they take courage from the example, provided, of course, society supports their work financially. This is clearly the case in Bulgaria with its present 3% expenditure on S&T.

If this be a social law, then it would seem to me important that at least one member of the African or Arab or Islamic culture communities should make every effort to acquire first-class expertise in at least one of the sciences. This will then break the psychological barrier and all members of such communities should be able to produce great science if they set their minds to it. In this context, it is important that the advanced and the not so advanced members of the same cultural community freely cooperate with each other and build up true commonwealths of science. (Detailed plans for such societies have been suggested, particularly on pp. 307-323 in *Ideals and Realities*, 3rd edition, World Scientific Publishing Co., Singapore, 1989.)

42

Cooperation for Development
in the Third World

I have always been convinced that science is a heritage of mankind and that, though the great developments of science have taken place in Europe and in the New World in these last centuries, there are no reasons why the poorer countries of the world should not contribute to its progress nor benefit from its fruits. In my undertakings, I have realized the importance of the value of partnership and of solidarity at all stages of my endeavors. Men of great talent – scientists, administrators, international servants, government officials and heads of state – have helped me in setting up several institutions in Trieste, the Italian city where I live most of the time, and in developing a world network of individuals and institutions who share our common ideal. In this article, I shall illustrate the base of what is now called the value of partnership in the scientific enterprise as I have lived it.

Science has flourished at different periods of human history in various parts of the globe, first in Ancient Greece (including Egypt, southern Italy, Turkey and Syria) and later in China, India, Persia, Arabia, Turkey and Afghanistan until 1400 AD, when Europe started to appear on the scientific scene. It was only after 1450 that the countries, which are now called Third World, started losing ground with respect to Europe.

Nowadays, science is carried out mainly in the Western World and in Japan. The practice of science has become expensive, particularly what is called “Big Science”, for example the study of the ultimate structure of matter, which is pursued in large particle accelerators like those in the USA or at the European Organization for Nuclear Research (CERN) in Geneva, or the study of space. Costs of such enterprises are so high that single countries cannot undertake these efforts alone. They must pool their funds, their scientists and their technological know-how. Equipment in less spectacular fields of science can also be expensive. For instance, high-pressure equipment for catalysis studies in chemistry can be worth several million dollars, not to speak of the cost of fast computers needed for weather forecasting and for climatology research. Spectacular progress has been achieved in the West because of the economic affluence, which followed its supremacy in technology, in manufacturing and managerial organization, and of

Reprinted from *World Science Report*, UNESCO, March 11, 1994.

the political will of governments to support either Big Science in a cooperative fashion with other nations, or domestic research in the universities or in specialized institutions. It should also be noted that although progress in science may be achieved through breakthroughs by towering individuals, advances in research are also due to collaborative work by teams which may be made up of as many as dozens or even hundreds of scientists.

Science is also a question of numbers. The number of scientists engaged in scientific research has increased considerably since the end of the Second World War. In 1990, according to UNESCO statistics, the industrialized countries counted 3,600 scientists and engineers engaged in research and in research and development per million population, with Japan and Israel leading with 5,500. On the other hand, the scientific panorama in the developing countries is totally different from the quantitative viewpoint. As a whole, the Third World can only muster approximately two hundred scientists and engineers per million population. The gap between North and South is as abyssal from this point of view as it is from the economic and quality of life side.

Besides the large countries like India, Brazil, Argentina and a few others, no country has a sufficient number of scientists to reach a "critical mass" that is to say the number of researchers who through their work, and their interactions with colleagues from within their own country or from elsewhere, would be in a position to produce significant results on a continuing basis.

In the colonial era, the scientific base of what is now called the developing world was non-existent, except for a few notable individuals like Bose and Raman in India. When most of these countries became independent in the 1960s, they had to start building their higher education and research practically from scratch.

It was precisely in those days that I began to ponder over the present and the future of science in my own country and in other developing nations. Coming back to my native Pakistan in 1951 after taking my Ph.D. in theoretical physics at Cambridge and after a research period at the Princeton Institute for Advanced Studies, I began to teach at the Government College, Lahore. In this position, I found myself desperately isolated. As the only theoretical physicist in the country, I had no one in my vicinity to talk to, to discuss or to share ideas with. The academic climate was not stimulating at all. After three years, I realized that staying any longer would not make sense; my work would deteriorate, the heaviest of my achievements in physics would go to waste and I would be of no use to my country. I reluctantly decided to return to Cambridge, joining the club of the many Asians and Latin Americans who before me had chosen to migrate to the more stimulating research institutions of the North. I sailed back to Europe with the determination to invent something that I could present to the men and women of the developing countries who were faced with the dilemma of either staying in their home country and dying professionally or migrating to the North and remaining competitive scientifically. From those days onward, my working

schedule became divided into two parts: one for research and one to think of ways to combat the brain drain and to help scientists from the developing South to give full measure of their talent. From Cambridge, I moved to Imperial College in London, where the Department of Theoretical Physics was founded in 1957.

During all this time, I dreamed of a place where theoreticians from both the developing and the industrialized countries could work together, in a stimulating environment for research, with a good library and, for those who need them, good computing facilities. This dream started to materialize in 1960 when, as the representative of the Government of Pakistan at the General Conference of the International Atomic Energy Agency (IAEA) in Vienna, I proposed the creation of an International Centre for Theoretical Physics (ICTP). This was a first step towards a large movement of partnership between organizations, governments and individuals. After the International Centre for Theoretical Physics, my efforts were geared towards the creation of the Third World Academy of Sciences (TWAS), the Third World Network of Scientific Organization (TWNISO) and the International Centre for Science and High Technology (ICS). The setting up of the International Centre of Genetic Engineering and Biotechnology with seats in Trieste and Delhi, in 1983, was also inspired by and large by the ICTP model.

Creating a center, as I envisioned it, was, for the IAEA, quite an unusual proposition in those days. While the proposal was enthusiastically supported by the developing countries, it met with the indifference of the industrialized countries, with the exception of the then USSR, Denmark and Italy. A preliminary study was made by eminent physicists and, following their recommendation, an international seminar on theoretical physics was held in the summer of 1962 in an outbuilding of the Miramare Castle in Trieste. This seminar proved to be a successful testing ground for the new center. Finally, after several debates at the IAEA Board of Governors and General Conference, the ICTP was set up in a provisional seat in Trieste, Italy, with an annual budget of US \$300,000 provided by the Italian Government, US \$55,000 by the IAEA and US \$20,000 by UNESCO.

Offers to host the ICTP had been received from several countries, but the package submitted by the Italian Government and the local Trieste authorities was by far the most attractive. It included, in addition to a contribution toward the functioning of the Centre, the provision of a new building (which was made available in 1968) and a first collection of scientific books and journals for the library. Later, the Italian authorities were to provide a guest house for one hundred people (1983) and for the doubling of the capacity of the first building in 1989. A third building, which will host all services of the ICTP, and also financed by the Italian Government, is presently under construction in the vicinity of the main building.

The ICTP took off rapidly as a multidisciplinary research center of excellence. Outstanding results in high-energy physics and in plasma physics were published during the very first month of existence of the new center.

Eminent physicists from the advanced countries were lured by the prospect of working in a place where they could discuss with colleagues from the Third World, share their experience and help those who need their advice. In those Cold War days, theoreticians from the Soviet Union worked together with specialists from the USA and Western Europe for about two years, in plasma and fusion physics – a field, which had for a long time been classified. The scientific reputation of the ICTP was established right from the beginning.

The necessary condition for the Centre to be useful to the scientists of the Third World was also accompanied from the ICTP's inception by the development of several modalities which were created to help physicists from the developing world to be able to resist the temptation of migrating to the attractive institutions of the industrialized countries, and to be trained at the highest possible level in research fields for which there were no opportunities in their home country.

The associateship scheme was the first of these modalities. An ICTP associate member is a physicist or mathematician from and living in a developing country who has already achieved important results in his or her discipline, and who is entitled by appointment to periodic visits to the ICTP spread over six years. As a norm, associates pay three such visits to the ICTP, each lasting not less than six weeks and no more than three months, with travel and board supported by the ICTP. In principle, these six-year appointments can be extended but, in practice, budgetary reasons impose limits on the number of extensions, since the roster of applicants is very large.

While at the ICTP, associates benefit from all facilities offered by the Centre, i.e., interaction with colleagues, the library and computing facilities if they need them. They have no other obligation than to do their own research. This guaranteed possibility of refreshing one's knowledge and accumulating ideas which will be worked out and developed at the home institution have proved to be an efficient deterrent against the brain drain. Former associate researchers may be appointed as honorary associates. These can use a fixed sum at their disposal for five years for short visits to the ICTP when their travel is supported by other sources.

For less experienced scientists, the ICTP designed high-level training courses – initially in nuclear and condensed matter physics – and a cost-sharing arrangement with institutions known as the federation scheme. Federated institutions are given the opportunity to depute their younger scientists to the ICTP for a total number of days per year, which varies from forty to one hundred and twenty, depending on the geographical distance from the institution to Trieste. These visits are used for participation in research workshops or in courses, or for meeting experts, collecting scientific data in the library, or using the computing facilities, when these are not adequate in their home country. Boarding expenses of the scientists are borne by the ICTP, while travel is normally paid for by the institution.

Again, this arrangement, which is renewed annually, provides federated institutions with the assurance of regular contacts with a dynamic research center and, as a consequence, opportunities for maintaining and improving their research standards. Some of these institutions (twenty for the time being) have been granted special status in recognition of their scientific achievements. Known as affiliated centers, these are granted US \$20,000 per year for five years for the further improvement of their research capacity.

In 1970, the participation of UNESCO in the running of the ICTP was formalized in an agreement with the IAEA. Through UNESCO's partnership, the ICTP was able to expand the sphere of its activities beyond the domains related to the mandate of the IAEA, i.e., those disciplines bearing by and large on the peaceful application of nuclear energy. Thus through the years, new topics were added to the curriculum of the ICTP. In the last decade, the ICTP has held, each year, from forty to fifty high-level courses, research workshops and conferences on subjects including fundamental physics (high-energy and particle physics, relativity, cosmology and astrophysics), condensed matter physics (solid state, atomic and molecule physics, materials and statistical mechanics), mathematics, physics and energy (nuclear, plasma and fusion physics and nonconventional energy), physics and environment (geophysics, climatology and meteorology, physics of oceans and atmosphere, desertification and soil), physics of the living state (neurophysics, biophysics and medical physics), applied physics (microprocessors, communications, optical fibers, lasers and superconductivity and computation physics) and physics teaching. Courses and workshops bring together from sixty to eighty participants from developing countries and last an average of four weeks. They are designed to bring the participants from a basic knowledge of the topic to state-of-the-art issues with hands-on activities, if need be in the laboratories of microprocessors, laser, fiber optics and high-temperature superconductivity, or with the ICTP mini-computer and the numerous personal computers available at the Centre.

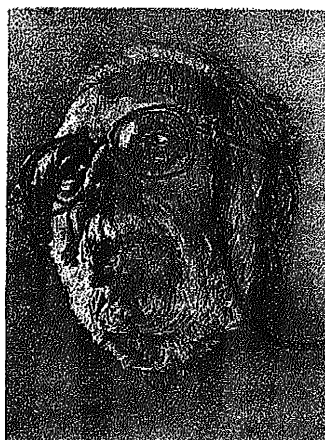
Every year the ICTP welcomes more than four thousand scientists from the Third World and from the industrialized countries. The average duration of stay of the latter is of the order of ten days, while the former stay for about five weeks. More than three hundred scientific papers are published each year by ICTP staff and visitors. Altogether, since 1964, the number of scientists from developing countries who have taken part in ICTP activities in one capacity or another amounts to 35,000, out of a total of 50,000 visitors. The success of the ICTP and its impact on research conditions in the Third World is due to the close partnership between the international organizations (the IAEA and UNESCO), the Government of Italy (which provides ninety percent of the budgetary resources of the ICTP), other organizations like the Swedish International Development Agency (SIDA), the local authorities of Trieste and the world scientific community as a whole.

By and large, ICTP courses and workshops address the needs of the theory-minded. For the experimentalists, a training-for-research program in Italian laboratories was launched in 1983. This program, which was initially financed by the Italian Department of Cooperation for Development, enables each year seventy to eighty scientists from the Third World to spend from several months to one year in academic or industrial laboratories located in Italy. The Italian National Institute of Nuclear Physics (INFN) and the National Council of Research (ENEA) provided additional fellowships tenable in their laboratories. Some three hundred laboratories are in a position to welcome fellows.

Scientists of the Third World must unite their forces. Without such unity, science in the developing countries cannot assert itself in the globalization of science and technology that we are witnessing nowadays. With this objective in mind, I discussed, in 1981, with my co-fellows of the Pontifical Academy, the idea of creating an Academy of Sciences for the Third World. Two years later, the TWAS was founded and, in July 1985, it was officially inaugurated by the Secretary-General of the United Nations, Javier Perez de Cuellar.

The main purposes of TWAS are to recognize and support excellence in scientific research performed by individual scientists from the Third World, to provide promising scientists in the developing countries of the South with conditions necessary for the advancement of their work, to promote contacts between research workers in developing countries of the South and with the world scientific community, to provide information on and support for scientific awareness and understanding in the Third World, and to encourage scientific research on major Third World problems.

At present, the Third World Academy of Sciences counts three hundred and eleven members from fifty-four developing countries, including nine Nobel Prize Laureates of Third World origin. ■

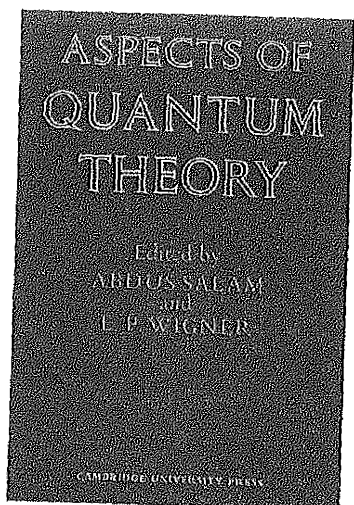


56. Sketch of Abdus Salam by Gulgee, 1994

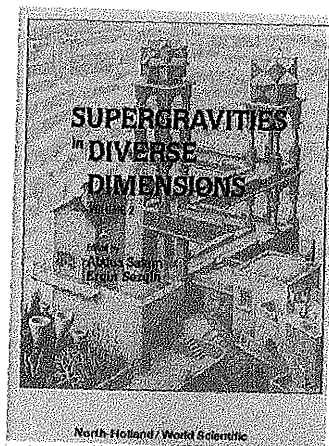
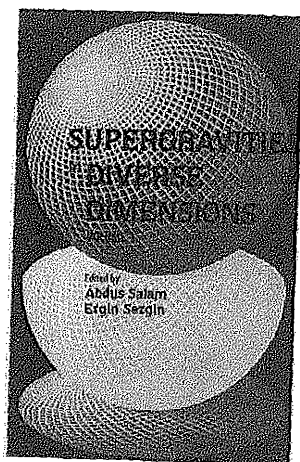
PART II. Tributes and Reminiscences



57. Portrait of Abdus Salam, 1965

58. Title Covers of Some Edited Books by Abdus Salam

Aspects of Quantum Theory (with E. P. Wigner, 1972)



Supergravities in Diverse Dimensions, Volumes 1 and 2
(with Ergin Sezgin, 1989)

43

A Pakistani Physicist Makes His Outstanding Contribution

The Pakistan Times,
Lahore

Very few people outside the small circle of the world's outstanding physicists happen to know of the contribution a Pakistani scientist has made to theoretical physics early this year. Fewer still know this achievement in his own country.

This Pakistani scientist is Dr. Abdus Salam, who recently succeeded Professor Hyman Levy to the Chair of Applied Mathematics and Theoretical Physics at the Imperial College, South Kensington, London, which is reputed for its outstanding achievements in the field of research, and which as a result has been selected as the central institution for the training of scientific manpower to meet the competition from other countries.

Professor Salam's contribution to theoretical physics relates to what is called the "Reflexion-symmetry Principle" or the "Principle of Parity". Four names are associated with the development and theoretical verification of this theory. They are those of Prof. Salam of Pakistan, Prof. Landau of the Soviet Union, and two Chinese scientists, Professors Yang and Lee of the United States.

Professors Yang and Lee were the first to question the correctness of the right-left symmetry principle which had been accepted by all physicists up to then, in a paper published by them in the summer of 1956, and they proposed a number of experiments to decide whether the principle held or not. These experiments were carried out by another Chinese scientist, Mr. Wu, of the USA, in the middle of January 1957 and the results confirmed the suspicions of Professors Yang and Lee.

Even prior to these experiments, Prof. Salam had predicted in November 1956 the exact results which the experiments would yield. He prepared a paper on the subject, giving his own conclusions and exact quantitative calculations, which he sent to the Italian journal *Il Nuovo Cimento*. This reached the editor of the journal on November 15. Earlier, he also sent a copy of the paper to Prof. Pauli, the Zurich professor and Nobel Prize winner, who is universally acknowledged as one of the world's top most physicists. But so firm was his belief in the correctness of the parity principle that when he received Prof.

First major article on Abdus Salam's work by a Pakistani newspaper published in *The Pakistan Times* (Lahore), August 20, 1957.

Salam's paper he sent back the message: "Give my regards to my friend Salam and ask him to think of something better."

Subsequently, after the results of the experiments were known, Prof. Pauli in his letters to Prof. Weisskopf, dated January 19 and 27, acknowledged having received Prof. Salam's paper several weeks before he got the paper of Professors Yang and Lee. Professors Yang and Lee themselves have acknowledged the fact that they had seen Prof. Salam's manuscript before they had written their own.

About the same time, a Russian scientist, Prof. Landau, working independently, developed the same theory in December 1956. Prof. Landau, who is the Head of the Soviet Institute of Theoretical Physics, is counted among the top-most world authorities on the subject. Prof. Mendelssohn, FRS, one of the five leading British physicists who had recently attended a conference in Moscow on physics, in a signed article in the *Sunday Observer*, paid glowing tribute to Prof. Landau. He said: "Landau's school of theoretical physics in Moscow has, at present, no equal anywhere in the world. It can be compared only with the Sommerfeld School which flourished in the twenties in Munich and produced many of the theoreticians now holding leading positions in the West. The flair for new ideas and original solutions, so assiduously fostered and encouraged, is an outstanding feature of Soviet physics, and the American witch-hunters have done the West a singular disservice by implying that Russian achievements depend on espionage. There is no doubt whatever that Soviet science can be completely self-sufficient, and that in any future interchange there will be as much give as take. Indeed, unless the Western Powers succeed in stepping up scientific development rapidly, they must face the possibility of becoming technologically inferior to the Russian within ten years."

It is, therefore, not the least surprising that Prof. Landau had independently arrived at the same results. His paper appeared in the journal *Nuclear Physics* in January 1957. Thus chronologically, Prof. Salam's paper came out a month earlier than that of Prof. Landau, which in its turn preceded that of Professors Yang and Lee by another month. These facts are already on record in scientific journals dealing with the subject and whenever the new theory is discussed in such journals the four names associated with its development are mentioned together, although in the popular press, especially in the West, the names of the Chinese Professors alone have come out. As soon as the results of the new experiments were known, Professors Yang and Lee received such a blaze of publicity in the American press that others who had preceded them in the enunciation of the principles were left in the penumbra of comparative obscurity. The American magazines, *Time*, *Life*, *Fortune*, *Scientific American*, and *Post*, of the same month published lengthy articles and Professors Yang and Lee shot into the scientific firmament as twin stars of blinding brilliance. The *New York Times* devoted four full pages to the report and published the full text of the manuscript of Yang and Lee, an unprecedented thing among daily newspapers in the West.

The new theory developed by the four scientists has a great bearing on the concept of elementary particles and is a valuable contribution to nuclear physics. It explodes the faith entertained by scientists from the day of Leibniz that nature did not recognize any inner difference between the right and the left. Since the time of Leibniz physicists had believed that in physical laws there was no distinction between the right and left – popularly speaking the existence of the right hand implies that the left hand also must exist. Since the right hand is the mirror reflexion of the left, the principle is called the “Reflexion-symmetry Principle” or the “Principle of Parity”.

As the British mathematical physicist and Nobel Prize winner Prof. P.A.M. Dirac has shown that for a particle there must be an anti-particle, the law of space reflexion asserts that if a particle exists, the one obtained by reflecting it in a mirror must also exist. If a reaction can take place, the corresponding reaction seen in a mirror is also a physically possible one. If right-polarized neutrinos can exist, so must the left-polarized neutrinos.

This principle has a philosophical appeal for many scientists. Apart from its philosophical appeal, this principle is known to be valid for all strong and electro-magnetic interactions. In the summer of 1956, Professors Yang and Lee pointed out that there had been no experiment so far to prove or disprove it for weak interactions, and therefore suggested a number of experiments which might determine whether this symmetry principle was true.

So deep was his faith in the correctness of the parity principle, that Prof. Pauli who is acknowledged as an eminent authority on the subject wrote in a letter to Professor V.F. Weisskopf, of the Massachusetts Institute of Technology, on January 17, 1957: “I do not believe that the Lord is a weak left-hander, and I am ready to bet a very high sum that the experiment will give symmetric angular distribution of the electrons. I do not see any logical connection between the strength of an interaction and its mirror invariance.”

Two days later he hastened to write another letter in which he said: “A quick addition to my last letter. Blatt has written to me that the experiment of Wu with the oriented nuclear spin gives a symmetric angular distribution for the electrons. Very exciting! How sure is this news? He also says that the neutrino and antineutrino are spatial mirror images. The Lord has in his left hand e^- in his right hand e^+ ”.

By this time he had also received Prof. Salam’s paper. In the same letter he also wrote: “This corresponds to an idea of Salam, who introduces a connection with the vanishing of the neutrino mass. This is equivalent with the description of the neutrino being a two-component spinor with zero mass, but why is this restriction of the mirror invariance only present with the weak interactions? Does anybody know about that?”

On January 27, Prof. Pauli again wrote: “Now after the first shock is over I begin to collect myself. Yes, it was very dramatic. On Monday the 21st at 8 in the evening I was supposed to give a lecture on the old and new history of the

neutron. At 5 p.m. I received three experimental papers by Wu, Lederman, and Telegdi. In the same morning, two theoretical papers came by Yang and Lee and Oehme about the two-component spin theory. (This theory originates from Weyl 1929, and was originally wrongly interpreted by him. My Handbuch article in 1932 reproduces my discussion about this with him.)

"This theory is contained in essentially identical form in an earlier paper by Salam, which I received as a preprint already six to eight weeks ago. I wonder if it is known in the USA.

"Now where shall I begin? It is good that I did not make a bet since it could have cost me a lot of money (which I cannot afford). This way I only have blundered in letters or orally and lost prestige (this I could afford, I think) but it is for you to laugh at me in this situation.

"I am shocked not so much by the fact that God is a left-hander, but by the fact that He still appears to be left-right symmetric when He expresses himself strongly. In short, the actual problem seems to be the question: Why are the strong interactions parity-symmetric? How can the strength of an interaction produce symmetry groups, invariances or conservation laws?"

Professors Yang and Lee to whom Prof. Salam had sent his paper did acknowledge the fact in their paper on "Parity non-conservation and a two-component theory of the neutrino". In Footnote 5, they wrote: "We have received a manuscript from Prof. A. Salam on a theory of the neutrino similar to the one discussed in the present paper. He specifically discussed points (A) and (B) that we discuss here. He also gave the Michel parameter for the mu decay that agrees with the ones obtained below in Sec. 6."

Prof. Salam once explained to a classicist the significance of this discovery in physics in terms of classical legends. He asked the classicist if he could recall any instance in classical literature of a legend about a giant with only the left eye. He admitted that one-eyed giants did figure in classical mythology and proceeded to name them one by one, but they all sported their solitary eye in the middle of their forehead. Prof. Salam said that the new theory revealed space as a left-eyed giant, and the pity of it was that there did not appear to be a right-eyed counterpart to it.

Returning instantly from this light-hearted digression into classical mythology, Prof. Salam in a recent lecture in London, explained the reason for the asymmetry. He said that one could give a deeper reason why the right-left symmetry should be violated whenever a neutrino was emitted. He said that it could be shown that an exactly zero mass for the neutrino was incompatible with the right-left symmetry. "We have lost the symmetry principle, but perhaps gained an exactly zero mass for the neutrino," he said. "Today the gain seems unimportant compared to the loss. A few years hence we may think differently."

Prof. Salam explained how he reached the conclusions before Yang and Lee had. He had heard of the work of the Chinese physicists in Seattle in September 1956. During a flight from New York to London, it struck him that in all the

experiments proposed by Yang and Lee, an elementary particle, the so-called neutrino, was emitted. It was long suspected that the neutrino has a rest-mass very close to zero. Prof. Salam could show by a simple argument that an exactly zero mass for the neutrino was incompatible with the right-left symmetry principle. Perhaps nature preferred that the neutrino should have an exactly zero-mass and was willing to sacrifice even the reflexion-symmetry principle to achieve this. Starting from this, Prof. Salam could predict exactly and quantitatively what the precise results of the experiments proposed by Yang and Lee would be. These experiments were carried out in the middle of January. Their results exactly tallied with the numbers Prof. Salam's calculations had produced.

The main credit for these experiments goes to a Chinese woman physicist, Mrs. Wu, who like Yang and Lee, is domiciled in USA. When the Chinese scientists received world-wide publicity Chiang Kai-shek's Kuomintang regime in Taiwan proudly claimed them as their nationals and conferred on them gold medals, and prizes of \$1,000 each.

Professor Salam, who succeeded Prof. Levy to the Chair of Applied Mathematics and Theoretical Physics at the Imperial College, is the youngest professor the college has ever had. He is only thirty-two. He is the first and only person from any Commonwealth country to occupy this position and the first Asian to be appointed to the Chair of a Science faculty in any university in Britain. Professor Radhakrishnan, who had once occupied a Chair at Oxford University, was a Professor of Indian Philosophy.

Prof. Salam was born in Jhang, in West Pakistan, in 1926. He had a brilliant educational career. He was a First Class student throughout and topped the list in the Matriculation, Intermediate, B.A. and M.A. examinations of the Punjab University. He set up a new record in the B.A. examination in 1944, which still stands. His distinction in the M.A. examination in 1946 won him a Government scholarship to join Cambridge University from where he took his Tripos in Mathematics in 1948 and Tripos in Physics in 1949 with a double first.

Subsequently, he was elected to a Fellowship at St. John's College, Cambridge, in 1951, for research work in Meson theory, and a similar Fellowship in the Institute of Advanced Study (Einstein's Institute), Princeton, USA. Returning to Pakistan with high hopes and still greater zest, he was appointed as Head of the Department of Mathematics, at the Government College, Lahore, in 1951, and in the following year he accepted the chairmanship of the Department of Mathematics in the Punjab University.

However, for a person of Prof. Salam's ability, attainments and inexhaustible zest for work, Pakistan hardly offered the opportunity or conditions for the full play of his talents. He yearned for the opportunity, but none was visible within his limited horizon.

When Prof. Salam was leaving England in 1949, Prof. Levy had made a prophetic statement. He said that if ever Pakistan found that it had no use for Prof. Salam, the Imperial College would certainly have a place for him. Prof. Levy's words came true.

In 1954, Prof. Salam was invited to join Cambridge University as a Lecturer in Mathematics, which position he held until early this year when he succeeded Prof. Levy at the Imperial College.

Shortly after assuming the chairmanship of the Department of Applied Mathematics and Theoretical Physics at the Imperial College, Prof. Salam delivered the inaugural address of the Mathematics Society of the college, on "Elementary Particles", which was attended by many distinguished personalities. Introducing him, Prof. P.M.S. Blackett, Nobel Prize winner and Professor of Physics at the college, said: "Dr. Salam had a meteoric academic career at school in Pakistan and seemed to possess an extraordinary facility for being unable to pass any examination in any subject except at the very top of the list. In 1946, he migrated to Cambridge and came to the greatest decision of his life, a decision which affected us here when he had to make up his mind whether to take an M.A. in English literature or in Mathematics. Luckily for Physics and Imperial College he chose the latter."

After referring in very eulogistic terms to the other aspects of his career, Prof. Blackett said: "In 1955, he showed his administrative gifts by becoming one of the scientific secretaries of the great international conference at Geneva on the peaceful uses of atomic energy. Salam's work in theoretical physics has been mainly of a very abstract kind, originally dealing with Quantum Theory of Fields, a subject of which I both do not know anything and know I'll never understand. Latterly he has gravitated towards the field of Elementary Particles, which is a very familiar and dear one to myself and to my young colleagues here in other parts of England and in the world, and this is what he is going to talk about today."

Prof. Salam has just returned to London after a visit to Argentina, Brazil and France. He spent two weeks at Buenos Aires lecturing on nuclear energy at the invitation of the Atomic Energy Commission of Argentina. He also had a week's stay at Rio de Janeiro where he delivered some lectures on the same subject. At the invitation of the French Government he visited the International Theoretical Physics Summer School at Les Houche where he gave a series of lectures. Next month he is visiting Italy to deliver a series of lectures on Elementary Particles.

44

The Lonely Scientists –
Thinking Ahead with Abdus Salam

Here and there among the multitude of people who are concerned about the dreadful dilemmas facing the underdeveloped half of the world are a few men who speak with special authority. They are products of the unindustrialized world, they speak for it, but they have also excelled in the West's own game of physical science. One of these men is Abdus Salam.

Salam is a 38-year-old Pakistani, a graduate of the Punjab University, a Muslim who is likely to include a quotation from the Qur'an in any public paper, the scientific adviser to the President of Pakistan. He is also a leading student of particle physics and one of the architects of the octet model, a fellow of the Princeton Institute, the youngest fellow of the Royal Society at the time he was appointed, professor of theoretical physics at Imperial College of Science and Technology in London. When I talked to him in London he was just about to take over the direction of a new international institute of theoretical physics.

Salam has a warmly personal manner. His speech conveys the impression of a man with a thorough command of a language not quite native to him – a new subject brings a pause, almost a stammer, while he gathers his thoughts, then an enthusiastic rush of talk. After we had spent a few moments getting acquainted and had settled down with cups of rich Turkish coffee, I asked my first question.

International Science and Technology (IST): Is there any opposition between the character of an Asiatic society and the spirit of modern technology?

Dr. Abdus Salam: I would like to say no. Take Japan. But, let me limit myself for the moment to Pakistan. Islamic society was highly technological in the 11th and 12th centuries when the Arabs were strong in the sciences. Even later, in the Turkish days, the technology of the Turks was not poor compared to the emerging European states. After I have said this, of course, I have to admit there are a number of factors in the way life is organized which will have to change if Asia is to become technologically modern.

IST: The question is how.

Salam: Up to a level, technology is easy. After one starts living in a technological society, one develops a sort of contempt for the thing. It's not hard. It can be acquired easily once the mental attitude towards it changes. It's not like scholarship which needs a long tradition to develop. Now take tradition: I keep

telling my boys in Pakistan, do not despair if you do not produce, for example, mathematicians like Hilbert, you still might produce mathematicians like Ramanujan. Ramanujan was, if you like, relatively untutored –

IST: *Intuitive.*

Salam: An intuitive person, one who could be produced anywhere at any time given a minimum of mathematical training. We could not produce overnight the solid tradition of scholarship which is typified by a Hilbert or a Weierstrass or a Gauss. Luckily, most technology does not need that long tradition of centuries scholarship does.

IST: *But where did you yourself come from?*

Salam: I come from Pakistan.

IST: *I mean – how did Pakistan produce someone like you?*

Salam: I don't put myself in the category of Hilberts. My subject is theoretical physics, and theoretical physics at the moment is in an intuitive state. It's at a stage when we are sitting on the top of experiments. We are utterly impatient. We don't want to wait from one resonance to the next. As soon as three resonances turn up, we make a complete theory. That theory is upset tomorrow; we don't worry; we start all over again. If you make mistakes, you don't worry. That is the intuitive milieu in theoretical physics. You need different types of gifts; you need good imagination, intuition, perception, seeking a correlation between facts. You do not need that long tradition of erudite knowledge.

IST: *This is a temporary condition, of course.*

Salam: Probably, in another few years things will change; the basic laws will have been established; the thing will become classical, less exciting. We shall need duller people with deeper scholarship. This just illustrates my point. For in technology, you are not looking for depths of erudition. Apart from a few basic things, the faster technology changes, the better it is.

IST: *How do you make it start?*

Salam: The most important step is breaking the mental barrier. You see, in my country, you preach a thing for five, six, seven years. You go on talking. Nobody listens. And suddenly you find – for example, take the civil service in Pakistan. The civil service was a legacy of the British Empire – men with liberal education, responsible for law and order and revenue collection. Sterling men, first rate administrators. But men with no appreciation of engineering, technology, or science. Not the men best suited for development. I personally do not wish the system to perpetuate. It is the sort of thing we have been crying out against for five, six, seven years. But in the last few years, suddenly we begin to find that a majority of the civil service men are sending their own sons to read

physics, chemistry, mathematics, and engineering – for research. You begin to wonder whether the barriers have suddenly begun to fall down.

IST: *What are the numbers like? How many young Pakistanis are studying technical subjects?*

Salam: Let's take the Ph.D. level. And let's concentrate on those being trained in the USA or the UK. Through our Atomic Energy Commission, which does not merely function for the atomic energy program, we have succeeded in training, in the last three years, something like five hundred men at the Ph.D. level. Now that's a tremendous number for a country like ours.

IST: *Will these men go back to Pakistan?*

Salam: Oh yes. They are all employees of the Atomic Energy Commission. They will go back to Pakistan. We are trying to throw them into the universities and into other spheres. So I should say we are taking care of the chemists and physicists and partly of the engineers. We are not taking care of biologists – that's a tremendous loss.

IST: *Not even agriculturists?*

Salam: Not at the moment. We have no organization to do what, for example, the Atomic Energy Commission does.

IST: *That seems absurd.*

Salam: It's absurd – absolutely absurd.

IST: *There seems to be an element of old fashioned intellectual snobbery in the choice of an education.*

Salam: You are quite right. As a rule it's the glamour subjects which get developed first. That seems to be the pattern all over the world. It's something to be deplored, in the abstract, but you can do nothing about it in a free society. First of all, the boys get more attracted towards the glamour subjects. Second, the government always puts up more money for them. But I do not despair. Once we get the government and the public used to the idea of spending on science, once that tradition develops, then that brings in the second round; the biological sciences, the prospecting sciences, the ones which are economically important get their share too.

IST: *And meanwhile, the thing is to encourage the glamour sciences?*

Salam: I am afraid one can't help it. There is a private enterprise in scientific selection, if you wish. One good man turns up in a country, and he has a bee in his bonnet – he only knows physics, he only knows nuclear engineering. These are the only things he can put his heart into. His force and the energy go in this direction. What can you do? Stop him giving of his best? Ask him to go back and read medicine?

IST: *Often this seems to mean theoretical physics.*

Salam: I am glad you said that. For it brings me to the venture, just now closest to my heart. Theoretical Physics is one of the few subjects where even a country with very little tradition of science can produce reasonably good people. Japan is a prime example; it wasn't as developed when theoretical physics started there. The Japanese school of physics preceded the heights Japanese technology has reached now. The same thing is happening elsewhere. There are one or two very good physicists in Turkey – one I know is commuting between Columbia and Ankara. A couple of very good Koreans; people from Lebanon; people from India, of course; a number of very good people. Some from Pakistan, some from South America – one or two outstanding men in Brazil, some very fine men in Argentina, and so forth. To my mind, these men are very much worth saving – not only because they are good scientists, but because they are the central –

IST: *What do you mean, saving?*

Salam: Saving for good science, within their own countries. They have the following problem. Theoretical physics is a subject in which – there's a Biblical phrase which expresses it – in which speech is the important thing, not the written word. You have got to go around and talk with people and be in contact if only to learn that this particular mess of papers here on my desk is rubbish and these others are the important thing. You can scan the whole blasted lot and never find out what is important. But going to an active place for a day, you can easily get to know the significant from the insignificant. So a man living in isolation or with a small group has every chance of just deteriorating.

IST: *He has students but no teachers.*

Salam: Yes. When I was teaching in Pakistan I had exactly the same problem. In Cambridge, and at the Princeton Institute I had done reasonable work. But at Lahore, I found myself getting out of the subject altogether. So when I was invited to a position at Cambridge, the only choice was to migrate, to make myself an exile. Now if somebody could guarantee those people who are living out there that they can maintain continuity, guaranteed continuity to come out once a year, for three months let's say, and to work in a stimulating atmosphere, they will stay on. They will not have the cruel choice of either giving up physics or their countries.

IST: *This is what your new institute will try to do.*

Salam: This is the project which is dearest to my heart at the moment. You see, in the world of theoretical physics there is the Western group, the United States and Europe, and there are the Eastern European physicists. No one recognizes that they exist, but there is also this third set of people. They may be as good in physics as some in the West or the East, but they have very unequal opportunities.

IST: *Do they also represent a different way of thinking?*

Salam: I definitely believe that every cultural tradition of the human family brings to science a different way of thinking. In theoretical physics I see some of the great Chinese physicists bringing the subject their pragmatism. Or take another example. I was recently discussing with Oppenheimer – though he did not necessarily agree. In mathematics or theoretical physics I do not know of any great Jewish complex variable men, or real analysts, but there are great Jewish set theorists, group theorists, and number theorists. This must come from the great Talmudic tradition. We speak now about symmetries in particle physics. When great Negro physicists arise, I wonder, in my lighter moments, if they will introduce the concept of 'rhythm' and 'harmony' in elementary particles.

IST: *So you see a third group in both an intellectual and a political sense.*

Salam: I do not wish to labor this point about intellectual diversity. But it seemed to me it would be an excellent idea to have an international institute of theoretical physics and one with a special emphasis on this need of underdeveloped countries. The idea started out at the Rochester Conference of High Energy Physics in 1960 with a remark by Mr. McCone. He was then Chairman of the US Atomic Energy Commission, and in his after-dinner speech, he said that it was time now to think of international particle accelerators. A few of us who met after the speech were commenting on it and we said, this is very fine, but let's start at least with a UN-run institute for theoretical physics.

IST: *How was the idea received then?*

Salam: It was opposed at first by the UK. It was opposed by France, by Germany, by Australia, and by Canada. It had only a lukewarm support from the USA and the USSR. We had no friends whatsoever among the great countries. But the idea caught the imagination of the developing countries – then nothing could stop it at the International Atomic Energy Agency meetings in Vienna.

IST: *But it wasn't set up at that time, was it?*

Salam: It was decided that governments should make offers of sites for the institute, and the IAEA would choose the most suitable among those offered. A bad way of proceeding – there was no rational discussion of the ideal place. The governments that made offers were Denmark – a million dollars for a building and about \$100,000 towards annual costs; Italy offered buildings and a quarter million dollars for annual costs; we also had an offer from Pakistan and an offer from Turkey. The Italian offer was linked to Trieste. Financially it was the handsomest so the decision was that the institute will be set up in Trieste for four years, and after that the situation will be reviewed, and if necessary it may possibly go to a developing country.

IST: *Would that be desirable?*

Salam: I would like to get the experience of seeing the thing run first. Trieste has some attractions. Somehow Eastern Europe is nearer; it's a semi-international city. Already we have had a tremendous demand for fellowships and senior positions from Eastern Europe – from the Poles, the Hungarians, the Rumanians, the Yugoslavs; also from South America; also from Asia. The institute will function at the beginning with a senior staff of about fifteen to twenty-five (mostly Ph.D.) fellows. There is also a new type of fellowship we have instituted. We call it "associateship". The "associates" – several dozen of them – are scientists from developing countries with the privilege of coming to Trieste at periods of their own choosing from one month to four every year. We shall pay their stay and travel.

IST: *It does seem strangely remote from the practical world as a way to help a developing country.*

Salam: Let us not confuse the full problem with a part of it. I did not suggest this was a panacea for all scientific deficiencies of the poorer countries. If I were an administrator in charge of science in Pakistan, I would certainly do my utmost to stress the basic agricultural and biological sciences. But let me make no bones about it. One needs, in addition, good scientists, first-rate scientists in pure subjects too.

IST: *The important thing is to develop a scientific tradition, no matter what science it is?*

Salam: It's not that. In a free society, it is a matter of the example. You must not underestimate what a great physicist can do for the morale of young people in a developing country. They come flocking in to read sciences, rather than literature or law. And another aspect of precept and example, I am pretty certain that this institute, if we can get the word spread that it is functioning the way we want it to, will breed a network of international institutes in other subjects – in practical subjects, like plant breeding or tropical medicine. Idealistically, it's the beginning of a UN university. So I don't despair.

IST: *A slow process. A generation.*

Salam: You don't need a generation. In some ways things are easier in a poor country; they happen in four or five years. That's a generation for us. With us the people you are trying to convince are few – paradoxically perhaps, but the pace is faster. ■

45

A Man of Science – Abdus Salam

Nigel Calder
Science Writer, London

One summer noon in 1940, Abdus Salam came cycling into Jhang, a country town in the Punjab region of British India. The townspeople had lined the streets to greet him because, at the age of 14, he had just made the highest marks ever recorded in the matriculation examination of Punjab University. The result was a national sensation, but nowhere more than in Jhang, which had so little tradition in schooling.

From that moment, Abdus Salam was public property. Scholarships were to relieve his family of the cost of his further education, first at Punjab University's Government College, Lahore, and later at St. John's College at Cambridge University in England.

Salam was to astonish the ablest men of his time and become a leader in theoretical physics. Today, at 41, he is international property. He directs the new International Centre for Theoretical Physics (ICTP) in Trieste, Italy, on leave of absence from Imperial College of Science and Technology, University of London, an institution similar to the Massachusetts Institute of Technology (MIT) in the United States. He is also chief scientific adviser to the President of Pakistan and one of the "wise men" entrusted by the United Nations with guiding the application of science and technology to the global war on poverty. But such public recognition says little about the man, or about his role in the world of physics.

Of course, Salam had been a child prodigy, but even his talents could have been stifled by neglect in his corner of the world. The boy had been lucky in his family circle, which has a long tradition of piety and learning. His father was a minor official in the farming community along a tributary of the mighty Indus River that gave India its name. Each day, when the boy came home from school, his father would question him closely on what he had studied. And if any other encouragement was needed, his maternal uncle, a former Muslim missionary to West Africa, supplied it.

As Salam's education proceeded, the traditions of Islam were complemented in his mind by Western studies. He read English literature as well as the Qur'an (sacred book of the Muslims). His prime subject was mathematics, but that would not have been sufficient to save him from the natural destiny of ambitious young men in his country – entry into the civil service. World War II had put a

moratorium on new appointments, however, so, in 1946, he went to Cambridge University to continue his studies.

Cambridge captivated him, especially the flower gardens of St. John's. Later he was to turn down a fellowship at neighboring Trinity College, considered the best college in Great Britain, for aesthetic reasons – the Trinity grounds were not as pleasing as those at St. John's. He became a *wrangler* (Cambridge's traditional term for a first-class mathematician) without much difficulty. Thereafter, Salam followed the advice of Fred Hoyle, the cosmologist, and took a course in advanced physics. "Otherwise," Hoyle told him, "you will never be able to look an experimental physicist in the eye."

Salam did more than take a course, he became a research student in experimental physics in the famous Cavendish Laboratory of Cambridge University. That move could have been a mistake. Salam was no good in the laboratory. He would get bizarre results in his experiments and explain them by inventing a new theory. He importuned the Cambridge theoreticians for something more to his taste. The rare self-confidence and fastidiousness of the young scholar demanded that he question the deepest qualities of nature.

To a Muslim mystic, Allah is to be sought in eternal beauty. And for Salam, beauty comes through finding new, subtle, yet simplifying patterns in the natural world. Anything that threatens to confuse the issue seems to him ugly, filling him with an almost physical revulsion and driving him to clean it away, much as one would remove mud from a shrine.

His first major piece of research, done at Cambridge, completed a vital cleaning operation to get rid of an absurdity in physics. In previous theory, there was nothing to stop an electron from having an infinite mass and an infinite electric charge. With great insight, physicists Julian Schwinger, Richard Feynman, and Freeman Dyson had indicated how the difficulty could be overcome, but the complete mathematical proof was lacking. That, Salam supplied.

During the period in which Salam has been active, since the late 1940s, physicists have shredded matter into smaller and smaller pieces, and have proposed new theories to explain them. In all the great advances, Salam has been in the thick of the action. Three of his contributions have been exceptionally important, and illustrate his quest for order.

The first had to do with parity – a theory of physics concerning the symmetry between an event and its mirror image. When a radioactive atom throws out an electron (beta particle) it also ejects that most elusive of particles, the neutrino. Both particles spin as they go, and the natural assumption was that the particles were just likely to spin to the left as to the right. At a conference in Seattle, Washington, in 1956, the Chinese-born American physicists Tsung Dao Lee and Chen Ning Yang suggested that such parity of left and right might possibly not be the case.

The startling proposal, which challenged a 30-year-old law on the conservation of parity, nagged Salam as he flew back to England from the Seattle conference. If the ugly, irregular idea of "parity non-conservation" was to be tolerable at all, there had to be a beautiful explanation for it. He recalled that no one has satisfactorily explained why the neutrino had no mass. Any particle will tend to interact with its own field and thereby resist acceleration which is what we mean by mass. Salam saw that nature could dodge this outcome if the neutrino spun only in one direction – in other words, if parity was violated.

More precisely, parity violation had to balance parity conservation exactly. That would mean that of the electrons emerging with neutrinos from radioactive cobalt-60 atoms, an average of three electrons would spin one way to every one that spun the other. By the time his plane had landed in England, Salam had it all clear in his mind. Distinguished colleagues mocked the idea. In 1957, Chien-Shiung Wu of Columbia University in New York City performed the celebrated cobalt-60 experiment that proved the violation of parity – God was left-handed, as Austrian physicist Wolfgang Pauli put it. For every three electrons spinning to the left one spun to the right, just as Salam had predicted.

But Salam, like many other physicists, was already after bigger game. Could the bewildering variety of particles be elementary? Or, was it, as Salam asked, that "some are more elementary than others?" The best thing was to seek family groupings, enabling one to say that if one particle exists, then others should exist with familial properties – similar but not identical.

The breakthrough began in 1960, when Yoshio Ohnuki of Nagoya University in Japan introduced the idea of "unitary symmetry" that might exist among particles. It started with the notion that most particles are made up of three entities which are themselves related to one another. Salam was the first non-Japanese physicist, perhaps in sympathy of oriental minds, to accept the idea. Thus Imperial College, where Salam was professor of theoretical physics, became the center of development of unitary symmetry.

Salam and John Ward, a visitor to Imperial College, used it in April 1961, to predict an eightfold family of new particles having twice the spin of the proton, duly discovered some six months later. A research student working with Salam, Yuval Ne'eman from Israel went on to show that the chief heavy particles, including the proton and neutron, also formed an eightfold family. About the same time, Murray Gell-Mann of the California Institute of Technology came to the same conclusion. He used the symmetry concept to predict a very strange particle – the omega minus – and when that, too, turned up early in 1964 the unitary ideas were established.

The next great advance came from American theorists who extended the unitary symmetry idea to link up separate families of heavy particles into a dynasty of fifty-six particles. But this theory left out the crucially important ideas of relativity, which omission launched Salam onto his third major contribution to

science. This time, working with two associates, Robert Delbourgo and John Strathdee, Salam introduced Einstein's "four dimensions" (three dimensions of space, plus time) to arrive at a still higher pattern. "We are never going to be surprised by the discovery of a new particle again," Salam commented at the time. The earlier theory, leading up to the omega minus, had flaws, and these were carried over into the new theory, as Salam's fellow physicists were quick to point out. The fact remains that the valid portions of the theory represent the highest level of pattern-making in particle physics. As Salam puts it: "We have now run out of indexes."

According to Muslim colleagues, physics, for Salam, is a form of prayer. But he also treats physics as great fun. He holds onto the problem in his mind like a dog with a bone, yet he manages to remain relaxed. He pours out ideas in continuous stream in discussions with his colleagues. Occasionally, Salam is right – and then his triumphant "I told you so!" might be irritating to anyone who recalled the ninety-nine others, voiced with equal conviction, that were wrong.

The intensity of feeling and humor that goes into his theorizing were illustrated once when he was ill. "I'm sorry," he told a colleague, "I can't do physics now because I can't shout back at you." Generally, Salam talks quietly, thoughtfully, and fluently in a husky voice punctuated by laughter. But he always takes a positive attitude to ideas. "Some theorists are nihilists," he complains. "They are very good at showing where ideas are wrong, but they do not offer anything in their place. I prefer to build." He thinks more or less continuously about the patterns of nature and their mathematical representation, looking for order and beauty. "A broken symmetry breaks your heart," he says. He begins his day at 3 a.m. Like the wise man in the proverb, he goes to bed early, too.

That, then, is the story of the scholarly Punjabi boy who became an outstanding physicist. But there is another Salam: the man of the world in the most modern sense, a man concerned with the politics and organization of science, and with the terrible problems of poverty and backwardness in his homeland and in half the world.

In 1947, while Salam was finding his place in the unfamiliar world of Cambridge, the British dissolved their Indian empire and the new Muslim nation, Pakistan, came into existence. Four years later, at the age of twenty-five, Salam went back to Lahore. He served as teacher of mathematics at his alma mater, Government College (1951 to 1954), and head of the mathematics department at Punjab University (1952 to 1954). He felt a duty to return home and work among and teach his own people. The move turned out to be unfortunate, although Salam did not give up easily. He spent three troubled years there before professional frustration drove him back to England. Reluctantly, he went down the "brain drain" which robs Asia of much of the talent that it so urgently needs. But he resolved to do all he could to save other young men from the "cruel choice" between homeland and profession.

At Lahore, the lack of facilities was the least of his worries – a theorist, after all, works with plain paper or a blackboard. But, the academic climate in Pakistan was wrong; science was ignored not only by the intellectual leaders of the new nation, but also by the brightest students. Salam, simply, was intellectually lonely. He dabbled fruitlessly in cosmology and the theory of superconductors. "You have to know what other physicists are thinking," he says, "and you have to talk to them. I feared that if I stayed in Lahore my work would deteriorate. Then what use would I be to my country?" Better to be a lecturer in Cambridge than a professor in Lahore.

Salam picked up the threads again with instant success. In 1955, he was asked to serve as a scientific secretary at the first Atoms for Peace Conference convened by the UN in Geneva, Switzerland. Like many others on that famous occasion, Salam was greatly moved and sensed the full strength of world science and its power to work great wonders for the benefit of all men. Two years later, he was chosen to found a department of theoretical physics at Imperial College. He was also elected the youngest fellow of Britain's most select association of scientists, the Royal Society.

Today, Salam is director of his International Centre for Theoretical Physics in Trieste. The possessive "his" is correct. Abdus Salam conceived the center as a place where men from all countries could work alongside some of the most distinguished minds of physics. As delegate from Pakistan, he proposed its creation to the International Atomic Energy Agency (IAEA) in 1960, and he was himself appointed its first director in 1964. Advanced countries, such as France, Great Britain, the Soviet Union, and the United States, were cool to the idea at first, but they could not resist the enthusiastic support from developing countries that rallied behind Salam. The Italian government provided the greater share of the money for the center's first four years, donated temporary premises and began work on a fine new building at the coastal resort of Miramare.

The advance that established the center on the scientific stage and made it a magnet for the world's physicists was Salam's effort, along with Delbourgo and Strathdee, in carrying the unitary symmetry ideas forward. That work was announced within a few months after the center had opened in October 1964.

The center, which Salam envisions as the first department of a UN university provides a meeting place for leading theoreticians of East and West. In 1965, for instance, Salam arranged a year-long brain-storming session on the attempts to tame the H-bomb – to produce useful power from the hot, heavy gas. Out of the session, presided over by Marshall Rosenbluth, an American, and Raoul Sagdeev, a Russian, came something like an international policy for experimental work aimed at giving mankind access to an unlimited source of power.

Closest of all to Salam's heart is the center's role in ending the loneliness of men working in the academically under-developed countries. Never again should any able theorist suffer the isolation that Salam himself felt when he went back to Lahore. From Africa, Asia and Latin America, professors and students come to

spend a few weeks or months at Trieste, where they can "plug in" to the current excitement of physics, sample the latest ideas, and, most important of all, meet informally with the world leaders in the subject. One device pioneered by Salam is already being taken up in other institutions and has attracted special support from the Ford Foundation. It is the "associateship" plan whereby selected theorists in developing countries are given the privilege of coming to Trieste for three months a year, with the center paying all the expenses.

The winter at Trieste is the time when many physicists come from the Southern Hemisphere during the summer vacation of their universities. It is for the scientists a time for renewal, an opportunity to communicate with kindred spirits. After teaching for four years at the University of Santiago, Chile, Igor Saavedra felt like "a squeezed lemon". He was tempted to accept a job in London, but the center at Trieste opened in the nick of time, keeping Saavedra from joining the "brain drain". For East Europeans, Trieste is, above all other considerations, the only place in the world where effective collaboration is possible between the physicists of the East and the West. Salam is also gratified that, through the Centre, important contributions to the subject by theoreticians from the developing nations in Africa have begun to appear.

Salam presides benevolently over the Centre, aided by his deputy, Paolo Budinich of Italy. Few of the visitors can know what battles Salam has fought and goes on fighting to make sure that the Centre will survive. In February 1967, for example, he took the night train to Vienna to talk to the governors of IAEA into extending the Centre's life indefinitely. He did not succeed, and he did not conceal his wrath. In former days, a Muslim warrior would draw his sword; Salam unleashes his words. He subscribes to the Islamic tradition that patience is a virtue only up to a certain point and gentle persuasion only for so long if you are striving for higher goals.

Abdus Salam's name means, literally, Servant of Peace. The ideal of human brotherhood cultivated in the abstruse mathematics and broken English of the Trieste Centre finds a broader and plainer expression in Salam's work for the UN Advisory Committee on Science and Technology. Twice a year, he and seventeen other men of learning spend ten days together at one of the UN's centers - Geneva; New York City; Paris, France; and Rome, Italy. They try to specify ways in which scientific knowledge and technical skills can hasten the advancement of that half of the world now living in poverty.

The UN committee has produced a "World Plan of Action" for building up science and technology within the developing nations and for transferring technical knowledge to countries that desperately need it. The "wise men" have also named particular technologies that need to be developed as fast as possible, such as desalination and the elimination of disease-bearing insects. Each member has his special pre-occupations and enthusiasms. Abdus Salam is particularly interested in involving leading scientists of advanced countries in the problems of world development.

On behalf of his own country, Pakistan, he did just that in a memorable fashion in 1962. The magnificent irrigation system built in the Indus Valley during the British era had deteriorated. Many years of seepage from the great irrigation canals had waterlogged huge areas of farmland, while evaporation from the soil had caused salts to accumulate. When Salam explained the problem, the U.S. government sent leading scientists, agriculturists, and engineers to West Pakistan. After thorough studies, the team, led by Roger Revelle, then director of the Scripps Institution of Oceanography at La Jolla, California, and science adviser to the Secretary of the Interior, drew up a plan of wells and pumps for draining the land and washing out the salt. Several areas, each about a million acres in size are already successfully under treatment west of Lahore. Over 30,000 farmers have adopted this procedure, greatly increasing agricultural production in West Pakistan.

President Ayub Khan of Pakistan appointed Salam as his personal scientific adviser in 1961, and a close and informal relationship has developed between them. Salam is frank about the human impediments in Pakistan, as in many developing countries, where scientists may proffer constructive suggestions, only to find them ignored by the administrators or dismissed because of the lack of resources to carry them out. Salam's most powerful colleague is Ishrat Husain Usmani, chairman of the Pakistan Atomic Energy Commission. The Commission has gone beyond its basic task of introducing nuclear power. It seeks to encourage general excellence among Pakistanis scientists.

In the words of Usmani, "Most of the scientific effort in Pakistan is in a large measure due to Salam's imagination and the weight of his personality. Salam is a symbol of the pride and prestige of our nation in the world of science."

At the same time, Salam confesses that too little attention has been paid to food and agriculture and he is understandably prone to pessimism. In a forecast of the future, he has written: "Twenty years from now the less-developed countries will be as hungry, as relatively underdeveloped, and as desperately poor, as today." Yet he recognizes slow progress in some directions. In Pakistan, the undue esteem given to the arts, at the expense of science, is being broken down. The president himself has come to share Salam's passionate interest in the publication of better science textbooks. Many people are studying science at the universities.

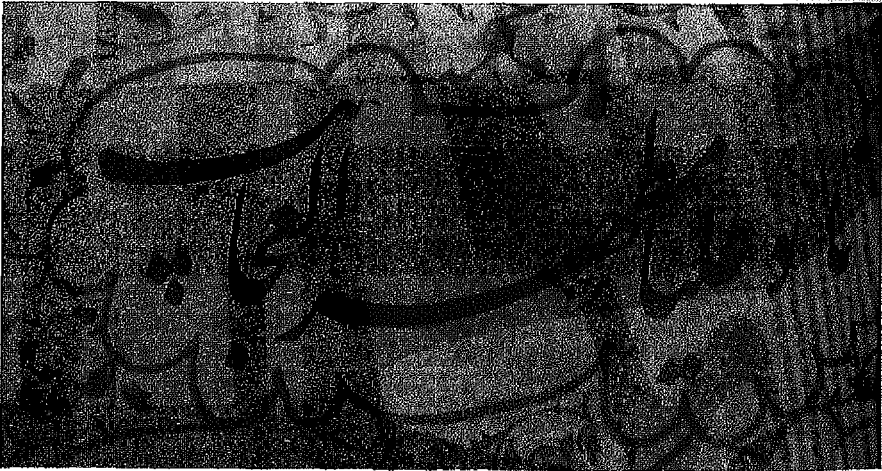
Since childhood, when he watched the apothecary at Jhang concoct aromatic sherbets from the ancient book of Avicenna, the Persian philosopher-physician, Salam has taken a proud interest in his former glories of Islamic science and literature. He likes to recall the days when Baghdad and Moorish Toledo were, for a time, the world's chief centers of learning. Even today, his vision of the future of Pakistan is not confined to the satisfaction of material needs. "Once a nation starts to think of higher things," he says, "scholars must find a role in that society." During his visits to Pakistan, it is not unusual to find him surrounded by

a group of poets reading their verses to him and finding him an appreciative and critical listener.

In keeping with strong Islamic tradition, "Charity begins at home," no young Pakistani seeking help or guidance from Salam is left unaided. His Western students, too, find him generous to a fault in his support of them.

Salam is frequently on the move from continent to continent, yet unlike many of today's jet set scientists he refuses to let public business deflect him from his personal researches. Conversely, in his advisory work in Pakistan and for the UN, he does not allow his scientific sophistication to dampen the simple passion of a man born in a poor community and who knows that he is perhaps the luckiest of all his countrymen.

On the wall of the director's office in Trieste, hangs an inscription of a 16th century Persian prayer: "O Lord, work a miracle!" Salam's strength is that he believes miracles are possible provided one goes out and helps them on their way.■



59. Salam's Favorite Calligraphy : "O Lord. Work a Miracle"

46

"Sanad" by King Hassan II of Morocco

Doctor Ahmad Abdus Salam, Nobel Prize,

CONSIDERING the renaissance of Morocco in various fields of activity:

CONSIDERING the geographical position occupied by Morocco which makes the country an important link or meeting ground for peoples and nations, and which has acted throughout the centuries as a bridge over which Arab-Muslim civilization has crossed; a land which has welcomed and adopted other civilizations, in particular western civilization:

CONSIDERING this special position which enables Morocco to undertake the defence of spiritual and ethical values common to nations which may differ in their beliefs and forms of expression:

CONVINCED of the importance of these spiritual values for the development and progress of these peoples in their forward march:

DESIROUS of seeing Morocco make an effective contribution to the promotion and development of study and research in every field: education, literature, culture, art, as well as in science, technology, economics, diplomacy and politics:

CONSCIOUS of the value of exchanges of views between the cultural and scientific leaders of different nations:

CONSCIOUS of the creative and enriching effort made for a better understanding and mutual appreciation between the Moroccan people and those with whom we are linked by ties of friendship and co-operation:

CONSCIOUS that many people share our faith in the values we hold in common, and which have been granted to by universal civilization, the transcendence of the human mind, and a fervent desire for the consolidation of peace and the achievement of humanity's noblest ideals:

WE HAVE DECIDED to found the Academy of the Kingdom of Morocco which we hereby place under Our High Patronage, in virtue of the Dahir dated 24 Chaoual 1397 (October 8, 1977). This law states the objectives of the Academy, defines its structure and prescribes the regulations for admission.

Presented on the occasion of the nomination of Abdus Salam as an Associate Member of the Academy of the Kingdom of Morocco, Rabat, March 11, 1980.

جالة لملك المغرب الملكة المغربية

المقدمه

والسلام والسلام على من لا نبي بعده

الوكيل احمد عبد السلام

نظرا للنهضة التي يشهدها المغرب في مختلف الميادين،
ونظرا لموقع المغرب الجغرافي الذي يرض عليه الاصطلاح بدور بارز
يجعله عامل ربط وتآلف بين الأمم والشعوب، والذي كان - عبر التاريخ -
جسرا مفتوحا لنشر وتبليغ الحضارة العربية الإسلامية والمستقبل
وتنقل ما جاز به الحضارات الأخرى ولا سيما الحضارة الغربية،
ونظرا لما يمكن أن يؤده المغرب من جلائل الأعمال في سبيل الدفاع
عن القيم الروحية، معنيها في ذلك جهوده إلى جهوده التي يتمتعون
هذه القيم أساسا لسلوكهم كنهما كانت معتقداتهم وأيضا كان تشكل
ونظرا لتبنيها.

وأما آثار رسالة الفكر وأثره الفعال في تعدد حيوية الشعوب
واستثمارها من مصلحتها، وتبنيها خلقاتها على طريق التقدم والرفق،
وجزا على أن تسهم المملكة المغربية مساهمة إيجابية وفاعلة في
ادراك وتوسيع وعي البحث والمزاولة في المجالات العلمية والأدبية
والفنية والثقافية والترفيهية والاقتصادية والتقنية والديبلوماسية
والسياسية. وذلك بإحداث مؤسسة علمية تروك الجهود والشاغل
التي تقوم بها سائر أجهزة الدولة في الميادين المذكورة.



وأدراكا لقيمة التعاون العلمي والفكري بين الرجال الذين يمثلون
عائلات أجيال الثقافة وعياديين القصص، ولما يمكن أن يفضي إليه
هذا التعاون الملاق من توطيد عرى التقارب والتعاون بين شعوبنا
والشعوب التي تربطنا بها وشائج المودة والتعاون، وبميراثنا منها
الآيمان بالقيم الروحية والفكرية والعقائرية المشتركة، ونشأ منها
الريحية في توطيد السلام وخدمة المثل الإنسانية النبيلة والهادية
فقد أصدنا أكاديمية للمملكة المغربية، ووسعنا هاديت رعايتها
الهادية، وهاديت بموجب ظهير شريف بمثابة قانون صادر بتاريخ 24
شوال عام 1397 (8 أكتوبر سنة 1977)، يحدد أهداف الأكاديمية
ونظمها ومبناها وأجهزتها ونظامها ونظمها فيها.
وبما أن الفصل الرابع من الظهير المشار إليه يقرر أن الأكاديمية
تتألف من ستين عضوا، نصفهم من مواطني المملكة ومجملون نصف
أعضائها متجهين، والنصف الآخر من الشخصيات المنجزة لخصائص
أجنبية ومجملون نصف أعضائها متجهين،
ونظرا لمكانة الرفعة، ومزايك الإنسانية والمهنية العالية
ولما تقتضيه به داخل بلادكم وخارجها من كفاية ومسيرات واسعة،
ولأهمية جهودكم المتفرقة في حقول الفيزياء والرياضيات، وادراكا للتواصل
على تحقيق سلسلة من الانتصارات العلمية الرائعة، مما جعلها ماضيا
محل تقدير وتأييد عالميين باعتبارها مشاركة مشرفة للفكر الإنساني
والحضارة الإسلامية، ولما ساهم في ميدان علمي له تأثير كبير على
تقدم البشرية جمعاء، الأمر الذي توج مجهدهم العلميين بمجملهم
على جازة نوبل التي لا يعطى بها إلا المبرزين من أمتائكم،
فقد أقررت عليا اللجنة التأسيسية التي عينها بمقتضى الفصل
الثاني والأربعين من الظهير الملحق إليه، ترشيحكم لعضوية أكاديمية



الأكاديمية المغربية بمقتضى عضوا مشاركا.
ونظرا لما تشتملكم والاعمال الجسيمة التي ما فندتم تبتذلونها
في مجال تخصصكم - لامتكم والإنسانية جمعاء - فقد وافقنا جميعا
على تعيينكم عضوا مشاركا في أكاديمية المملكة المغربية.
ونشأ كمال اليقين وبإيمان الثقة في أن إسهامكم القيم في نشاط
منا المؤسسة العليا وجهودها، سيكون له الأثر المجد في تحقيق
الأهداف التي نؤتيهاها من تأسيسها، كما ستكون مشاركتكم حاضرة
قوة لتوطيد أواصر الإحسان والتعاون بين بلدكم والمملكة المغربية.
وتقبلوا المسند عبارات تقديري.

حررا بالقصر الملكي بمركنش في يوم الاثنين 22 ربيع الثاني 1400
الموافق 22 مارس 1980

الحسن الثاني
ملك المغرب

"SANAD" by King Hassan II of Morocco
March 11, 1980

Article 4 of the organic law stipulates that the Academy shall comprise 60 members, 30 of them resident and citizens of the Moroccan Kingdom, and 30 Associate Members, persons of foreign nationality.

Taking into account your outstanding human qualities and your illustrious reputation, not only in your own country but also abroad, in view of your incomparable work in the domain of physics and mathematics, which has contributed to a series of successes in advanced scientific research, and which has earned you and your country – an Islamic land – renown and esteem which has radiated throughout all Muslim civilization:

In view also of your outstanding contributions to the progress of science, and hence of humanity, whose merits have been universally recognized by the award of the Nobel Prize, an honor bestowed only on men of your stature:

CONSIDERING all these qualities, the constituent commission appointed by Our Majesty by virtue of article 42 of the organic law has brought your name to Our notice for admission to the Academy of the Kingdom of Morocco as an associate member.

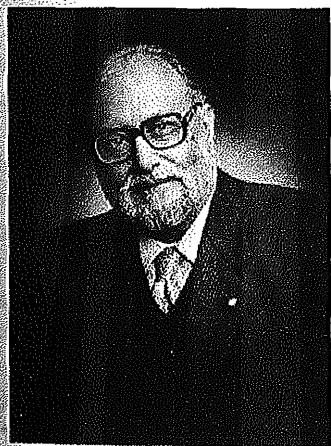
Further, in homage to your eminent personality, and in view of the valuable work you have accomplished for your country and humanity, it is with the greatest pleasure that we give our agreement for your nomination to the Academy of the Kingdom of Morocco.

Lastly, we are convinced that your participation will add a powerful stimulus to strengthening the links of friendship and cooperation between your country and the Kingdom of Morocco.

Promulgated at The Royal Palace in Marrakech

Rabia II, 1400

March 11, 1980



60. Abdus Salam



61. His Majesty King Hassan II

47

Professor Abdus Salam

Professor John Ziman
Professor of Physics,
University of Bristol, UK

Mr. Vice-Chancellor,

Only connect! That is the theme that runs through the life and work of Abdus Salam. He has followed the teaching of Islam, and has dedicated his life to the principle of unity – the unity of Nature and the unity of Mankind. As a natural philosopher he has seen that the various interactions of the elementary particles must be no more than diverse aspects of a single primary force. As a political and moral leader he has demonstrated that the various interactions of nations and cultures are no obstacle to the brotherhood of Man in science.

In the Faculty of Science, we honor him as one of the finest theoretical physicists in the world. In 1950, he was awarded the Smith's Prize at Cambridge for an outstanding pre-doctoral contribution to physics. Since then he has been continually at the working face of the deepest mine that science has ever pushed down into the bedrock of reality. He has a major part in every act of the unfolding drama of the discovery and understanding of the primary entities of quantum physics. It is astonishing that a man who is also so active in public affairs should have published some 200 papers on the physics of elementary particles, and is still forging ahead in that intensely competitive and dynamic intellectual enterprise.

In fact, he is still so hard at it that I have not dared to engrave a tablet of his achievements in physics: tomorrow morning, a new experimental observation somewhere might add a whole new theory to the list. Salam has the great scientific gift of suggesting new, physically realistic, theoretical connections that are really worth the effort to confirm. The great theory of the electroweak force, for which he shared the 1979 Nobel Prize in physics, was first put forward thirteen years ago. For the next three or four years it was totally neglected, because of apparently insuperable mathematical difficulties. When these had eventually been cleared away, some very delicate experiments were still needed

Presentation address by Professor John Ziman, FRS, on the occasion of the award of the degree of Doctor of Science – honoris causa by the University of Bristol, July 2, 1981.

to test the mathematical predictions against physical reality. I remember visiting him in Trieste at the exciting period, with telephone calls from continent to continent to check up on data that seemed, at first, to disconfirm his cherished hypothesis. Salam's personal enthusiasm for physics is delightfully infectious. It was a happy day for us, too, when his persistence was rewarded, and it came out right after all.

What that theory did was to show that certain well-known interactions between elementary particles, for example, the so-called 'weak' force that eventually drives every neutron to decay into a proton and an electron – could be treated as part of the much more familiar electromagnetic force that acts between all charged particles. It was a hard nut to crack. Compared with some of our modern mathematical physicists, Salam's methods are slightly old fashioned. But he uses such magic sledgehammers as gauge fields and renormalization theory with a delicate, practiced hand. Faraday and Maxwell would have been delighted with his achievement, which is a bit like their unification of magnetism itself with electricity, more than a century ago.

It is good to see science unfolding in the traditional manner. That was a scientific breakthrough in the old style. It has opened the way to yet another revolution in quantum physics, with the goal of a grand unification of all the forces of Nature now in clear sight. Perhaps this is only a mirage – or perhaps another of Abdus Salam's imaginative schemes for the ultimate construction of matter and energy has got it right, and will again be confirmed by the observation of a predicted physical phenomenon that cannot otherwise be explained.

One such prediction of his current theories is that protons themselves, the building blocks of all heavy matter in the universe, should not live forever. Just like neutrons, they should eventually be driven to transform themselves, into lighter particles and radiation, by a tiny component of a universal force. Fortunately, it is a very small effect. Our present-day protons should last a billion, billion times as long as the universe has already existed – which is surely a little longer than it might take – for me to master all of Salam's theories, fully, for myself, and then explain them very carefully to this assembly.

Perhaps, Mr. Vice-Chancellor, you will forego that pleasant exercise, and accept his world-wide scientific reputation as evidence of his eminent worthiness for an honorary doctorate in this Faculty. But first, let me present Abdus Salam to you in another aspect, as one of the first citizens of the World. He might be considered as just a leading British scientist, having been Professor of Theoretical Physics at Imperial College, in the University of London, for more than twenty years. But in fact he spends a good deal of his time in Trieste, in Italy, and is a frequent visitor to the United Nations, in New York. He is a sort of one-man multi-national corporation busily transferring intellectual technology to the less developed countries of the world.

His homeland is Pakistan, a country to which he remains deeply attached. He was born and brought up in the city of Jhang, not far from Lahore, that ancient paradise of Mughal palaces and gardens. From Government College, Lahore, a scholarship transported him to Cambridge, where he showed his mastery of all the mathematics and all the physics that any undergraduate could be permitted to study, and soon had his feet on the swiftly-rising escalator of research. On that brilliant early achievement and promise, he went back to Lahore as a Full Professor at the very tender age of twenty-five. In fact, by ordinary standards of academic success, he was now all set for a comfortable career.

But the next three years must have been the most miserable – and formative – of his life. The old Government College was previously one of the leading academic institutions of British India – but there was little interest in scientific research. As Salam recounts it, the head of the college offered him the choice of three college jobs for any spare time he might have after his teaching duties. He could become warden of the college hostel, or chief treasurer of its accounts, or, if he liked, he could become president of its football club. He says he was fortunate to get the football club – though I suspect that rival clubs didn't feel that way!

The most severe deprivation of those years was the loss of contact with fellow scientists working on the exciting problems of the day. As he analyzed it later, this was one of the main reasons for the dispirited research atmosphere in almost all the less developed countries. I quote: "Gifted men, from countries such as Pakistan, Brazil, Lebanon, or Korea, work in advanced countries in the West or the Soviet Union. They then go back to build their own indigenous schools. When these men go back to the universities in their home countries, they were perhaps completely alone: the groups, of which they formed a part, were too small to form a critical mass; there were no good libraries; there was no communication with groups abroad. There was no criticism of what they were doing; new ideas reached them too slowly; their work fell back within the grooves of what they were doing before they left the stimulating environments of the institutions at which they had studied in the West or the Soviet Union. These men were isolated, and isolation in theoretical physics – as in most fields of intellectual work – is death. This was the pattern when I became associated with the University of the Punjab at Lahore!"

Even a thoroughly self-winding genius, such as a young Salam, could not accept this danger of being slowly buried alive. In 1954, he came back to England, and was soon established in his chair in London. Although he never lost his close personal and professional contacts with his home country, and he takes special pride in being the first Pakistani to win a Nobel Prize, he has not returned to a regular academic appointment in that country.

But Abdus Salam is a man whose heart is as great as his mind. The memory of those anguished years of isolation did not turn sour within him; it became the creative kernel of his greatest achievement. He vowed to provide the means by which other talented young scientists, from less developed countries, could keep

themselves from scholarly death by isolation, without having to desert their native lands.

A single line in his biodata records that he has been Director of the International Centre for Theoretical Physics at Trieste since 1964. There is more in that title than the fifty awards he has won from universities and national academies around the world. He created that Centre out of nothing: it is now one of the most successful and respected international institutions of our times. Scientists from developing countries come to Trieste to get the latest scientific news, to learn the latest techniques, and to meet their colleagues from both advanced and developing countries. They come to attend advanced courses, or to work quietly in the library, to argue vehemently with some very bright young chap from Indonesia, or to acquire understanding and insight from a very wise old Professor from Sweden. It is a bustling railway junction of the intellect, bursting out of the handsome buildings it acquired only a few years ago, managed by the brilliant improvisations of a devoted staff, and always short of funds. Yet it lives, and works, and grows, and serves the whole world of the physical sciences.

How was it done? How did that most abstruse of young professors persuade the hard-headed delegates of lumbering international organizations such as the International Atomic Energy Agency and UNESCO, to put their money into such an out-of-the-way project? How did he so befriend the Italian Government that they gave such a support in cash and kind? In these past few years of declining funds and proliferating bureaucracy, how has the Centre managed to remain alive and flourishing, in the interstices of a system that has brought much grander projects to frustration?

The Trieste Centre was created, and continues to thrive, through a singular force – the personal will power of its Director. Let me warn you, Mr. Vice-Chancellor, that Abdus Salam is a manifestation of that imaginary concept of mechanics – the irresistible force. Suppose he asks you to do a little favor for him – say a three-week visit to the University of Vladivostok, you will find you have only three possible responses. The first is: “But Abdus that’s completely forbidden by my religion. I shall be damned to eternity if I go to Vladivostok in August.” The second is: “Very sorry, old chap, but all that month I’m absolutely committed to lecturing in Bogota.” Most commonly, however, the only remaining degree of freedom is: “Yes – how do I get there?”, and off you go. He seems to have that effect on everyone he meets – politicians, government officials, international bureaucrats and fellow scientists. He impresses and persuades by the integrity, purity and singleness of his purpose, put into the service of his fellow men.

Originally, the Trieste Centre was for the highest of pure science, setting standards of excellence for Third World physics at the most advanced level. But Salam’s own experience, both in directing the Centre and as a participant in science policy-making for successive governments of Pakistan from about 1960

to 1974, taught him to widen the objectives of science for countries struggling for economic and social development. Over the years, the program of associateships, advanced courses, seminars, workshops and conferences at Trieste has broadened, to foster and coordinate research in all fields of applicable science. Salam speaks now for the special role of the trained scientist in this development process and for the need for national and international scientific institutions which will make that role attractive and productive. He has thrown his personal charisma, and the immense prestige of his Nobel prize into a world-wide campaign to establish the essential infrastructure, that can give aid and advice to the smallest and poorest nations in their efforts towards self-development.

In both spheres of philosophy, natural and social, Abdus Salam strives continually to 'connect'. Along that way he has already achieved such a unification of Nature, such a realization of the ideal of human brotherhood, that it is very proper that we should do him honor.

Mr. Vice-Chancellor, I present to you Abdus Salam as eminently worthy of the degree of Doctor of Science – *honoris causa*. ▯

48

The Blindness of the Third World

Denzil Peiris

Science (meaning widespread dissemination of scientific knowledge and attitudes) and support for scientific institutions must precede the transfer of technology, Dr. Abdus Salam insisted when I talked to this Nobel Prize winner in his sparsely furnished cubicle crammed with journals and papers in the Physics department of the Imperial College in London. On a blackboard, embedded in one wall, he had set out a seemingly abstruse formula. Despite the heights at which his intellect functions, the professor is down to earth and informal. "Let this interview be rambling," he said. So, he ranged over the importance of basic science for the Third World, the arrogance of bureaucrats and lack of rulers with a vision. Yet all of these were strung on a single thread – what is it that frustrates science in the Third World? "The older I grow the more I feel amazed at the blindness of the developing world towards these really fundamental issues," an exasperated Dr. Salam said.

Abdus Salam: I was just interviewing a Greek student, he has read very widely and he came to ask "What should he do next?" I told him that it is very important for people in developing countries to realize that science is highly professional. The days when you thought you reached the truth without being a professional experimenter or a professional theorist are gone. I said our failure (and Dr. Salam meant the "developing countries") is quite often that we do not realize how much professionalism there is in science. Nor do our economists understand that when they ask for technical fix and think it can be provided on demand that they are wrong. Unless and until basic knowledge has been accumulated no technical fix can be achieved in this age when science must precede technology.

Take as an example the field of energy. The economist thinks that by spending vast quantities of money the energy problem will be solved by the technical people – "Oh yes, they will come up with a solution." Unfortunately, so far as the long term solution is concerned, this is not true. For example, at this stage there simply does not exist accumulated data of basic knowledge in the field of fusion or photolysis – splitting water into hydrogen and oxygen using solar energy – or the like, on which you may draw for solving ultimately this very complicated problem.

In the last century, there was a vast amount of purely scientific knowledge. But technical fixes from now on are going to take much longer. There will need

Abdus Salam's Interview with Denzil Peiris. *South*, Colombo, October 1981.

to be a scientific base which may not exist in many cases, and which will need creating. And this is more true for problems peculiar to developing countries, which the scientific community in the developing countries has had no reason to consider solving or accumulating ideas and data-bases for.

I spoke earlier of professionalism in sciences. Discovery in sciences is hard one has to eat one's heart out and one needs all the help one can get from those who provide administrative support for science in our countries. Unfortunately most of these people don't understand the process of science. Their thinking goes like this: "I have given this man the opportunity to do a Ph.D. Why hasn't he become the last word in the subject?" It is not realized that in science a Ph.D. is just a very first step. After that you need an apprenticeship of three to four years of continuous rubbing shoulders with your colleagues, to acquire maturity. Then you are able to produce some good work. And to produce good work in applicable sciences is even harder than in pure sciences. (Dr. Salam has set up in Trieste an institution at which theoretical physicists from all over the world come and meet their colleagues from developed countries in this field, and pursue their own research in an atmosphere congenial to creation of ideas.)

Peiris: You say you set up this institution at Trieste. And that is a very great idea. So there is one institution at least on theoretical physics which can do this. But what about other disciplines? None of us, individually, can afford to have a single such institute in our countries.

Salam: You are right in asking this question. When I started the Trieste idea I had hoped that there would be similar institutes in chemistry, in mathematics, geophysics, experimental physics; all the disciplines which we need very badly. I am talking of basic sciences. Regretfully, the idea has simply not been taken up by anyone else in other disciplines.

The people in rich countries do not need such institutes. They have their own and they are not going to do something for developing countries out of the goodness of their hearts. Nobody does this. The developing countries have to make a beginning. But most in our countries don't realize the importance of this. I was very glad to read recently that in Sri Lanka one of your bright young physicists now in this country (Britain), Dr. Nalin Chandra Wickremasinghe (professor of applied mathematics in Cardiff University), who has been working with Fred Hoyle had the idea of creating an institute like the Trieste Centre in Sri Lanka. I think he persuaded your president (J.R. Jayewardene) to help in its foundation. Last year I heard that it had been set up. I haven't heard anything more about it but it pleased me immensely because here was another initiative of the right kind. I think the whole ethos of starting such a thing in a developing country is a remarkable thing and I am pretty certain that it will lead to development of science in Sri Lanka.

Peiris: *Now do you see this as being done by one country or do you think it should be on a regional basis, and how would you set about it?*

Salam: I would have liked the following to have happened: I would have liked each country to specify one or two subjects. Not by the administrators but by the scientists. These centers could be on basic sciences or on the interface of basic and applied science or possibly, if the country is prepared for it, on purely applied subjects. The center should be international because that is the only way to maintain quality.

Such a center would cost one or two million dollars at least. Most countries of the developing world say they will not be able to afford it. Personally, I think they can afford it. The only worrisome thing is that such a thing would be out of line with what they are doing for the rest of their educational and scientific sphere. If you set up in the country an institute costing one million dollars there will be such a vast discrepancy with the desert around the institute that perhaps it will cause an uproar. I would welcome this, because it may pinpoint the fact that the rest of the scientific and educational effort is being conducted at a very low level of funding.

Peiris: *You would see a justification for it, nevertheless?*

Salam: I see a justification. What I was going to suggest was that at this stage funds like the OPEC fund, funds like the UN Interim fund, these should come into play and they should then help from external sources with some of the funding of such a center. That would be the pattern that I would have liked to have seen started. But such centers of excellence should be created on an international scale. Not on a national or regional basis.

Peiris: *Coming back to what you call "a center of excellence" — it is a massive peak rising out of the plain, with its underdeveloped basic science. What argument would you use to present the case for such an institute?*

Salam: In Pakistan, I am suggesting that there should be two centers which are both "applied" (sciences). One is a center for waterlogging and salinity. It is a very big problem of ours, and simply not enough research is done. The same problem exists in other countries as well. Then there is the second problem of mineral resources. I was suggesting that both these centers should become international centers. Examples of such centers in the applied field are the center in Mexico for wheat (CIMMYT) and the International Rice Research Centre in the Philippines (IRRI). The Pakistan government has asked the Italian government to help in setting up these. In addition, what has pleased me very much is that some industrialists in Pakistan have started to think in terms of a center for basic sciences. They are trying to gather some funds and set it up. It will cost about a million dollars, something in that order.

Now how would this center benefit Pakistan? Suppose this center specializes on basic biological sciences. From this could be born the movement towards

biotechnology. Or the center may specialize in quantum electronics, with applications to solid state devices. In this day and age when one can see that the material superiority of the West, and now of Japan, lies in sciences and technology, it only amazes me why our countries are so blind that they cannot understand this simple fact.

Peiris: *Isn't this something to do with economic structures? In the sense that the rich of these countries are more interested in serving as merchants, for one thing or in an inferior capacity as compradores. In fact, what you said strikes a chord. Mr. Homi N. Sethna (Chairman of India's Atomic Energy Commission) came back from Washington recently. He was addressing the Indian Chamber of Commerce. One member suggested that India should import technology straight away. This is the quickest way of making one's money.*

Salam: The industrialist was right so far as his money was concerned. There are similar so-called entrepreneurs, in other countries who would simply import ready-made goods. But is this good in the long run?

Yet even this class would realize that someday eventually they have to support their indigenous science and technology. And here the point I was making earlier was the distinction between science and technology. Science must precede technology.

It is just impossible to talk of technology transfer. One should talk of science transfer first, and technology transfer later. Today technology has nothing to do with the way technology was developed in the late 18th or 19th century, by trial and error. It follows science. Unless you are very good at science you will never be good in technology.

Peiris: *Basic science?*

Salam: Yes. By basic science I am not referring to the sciences of cosmology or of theory of numbers. I mean basic quantum theory which is at the heart of all solid state physics and eventually of solid state devices, basic mathematics for computing, basic modern biology at the heart of biotechnology and the like. And then there is craftsmanship. That's the pride in a craftsman. This is, of course, the second thing which has to be allied to science. I live in Italy. The degree of craftsmanship that you find there is allied together with very good science. For example, the craftsman needs materials. Modern materials are created by the scientist. They are produced by the technologist. They are worked on by the craftsman. There is a three-way collaboration. We must recognize this. No country has an excuse for not building up its scientific, its technological and its craftsmen base. I cannot find any excuse. I'm not saying great centers of scientific research should be set up on subjects which are totally irrelevant to a country's needs. I'm not saying that a poor country should be doing space sciences. But a certain degree of science. In Kenya they have set up a very wonderful institute of insect physiology. Some may say it has nothing to do with Kenya of today but it would be a very short-sighted person who would say that.

Peiris: *Wouldn't this have any links with pests?*

Salam: Of course it would. The few million dollars which Kenya is spending on it is, I think, one of the best investments being made. A fair fraction of the funds are coming from outside – from scientific academies.

But Kenya is to be congratulated. As you say it is the merchant mentality. How we can get rid of it, I don't know.

Peiris: *You were also talking at one stage about the fact that the bureaucracies are dominated by the classically trained people. Concentrating entirely on administrative functions.*

Salam: This is true of this country. My own feeling is that Britain's decline can in some measure be attributed to its non-professional bureaucracy. In contrast, France has a professionally trained bureaucracy, with roots in Ecole Normale Supérieure and Ecole Polytechnique. These great schools provide them with the civil servants who are at the top. People – like the former President of France, Giscard, professionally trained engineers, economists, technologists. I believe Renault – a state industry – is not run by someone with a training in Latin or Greek. Likewise, other enterprises of state are run by people who are professionally trained.

Britain, on the other hand, believes in the training of the classics. And we, for our sins, have inherited this tradition. Our top civil servants pass one examination at the age of twenty-three taking history and Persian as the soft options. That one examination determines the entire career. Whether you will be in the civil service or the foreign service, or the audits and accounts service.

We are told what we need are dedicated amateurs. We have not realized – this country hasn't realized – that the day of amateurs is past. Long past. The result is that you can see in twenty years this country has not half the GNP of France. It used to be twice that. I blame the civil service because the civil servant is the real backbone of any country. An incompetent civil servant is what destroys a country.

Peiris: *But do you see any way of stimulating this interest in science and technology? This is true of most developing countries that there is a lack of interest in science and technology.*

Salam: This is a very difficult matter. I think this is something that you can only pray for. [A long pause] You see I don't know how you can create at a certain time a class of men (of administrators interested in science) and let them have their head. It may happen by accident. For example, take this country in the last century. How did it consciously or unconsciously create the empire? There were men here who were motivated. But why? Whenever I visit the gaunt landscape of our northern frontier (of Pakistan) the thought comes to me: there used to be one Englishman in this whole division and he had the guts to say

"Here I am the ruler." What was impelling these men and where have they gone now?

The same thing is true for the science and technology. Either you get men who acquire science and technology and apply it in the service of society or you don't. I can see that some countries are coming up in this respect.

For example, just now I was talking with a Greek student. Greece has suddenly decided, for some reason, to take up science and technology. And it is fascinating to see their growth in my own subject, physics. I see many young people who are very good in physics. Greece has, because of the European Union idea, decided to join the Centre for European Nuclear Research in Geneva. That will pull them up more. Now Turkey is their neighbor. It has similarly gifted people. But Turkey has made no conscious decision to join the European Centre for Nuclear Research. In the case of Greece they have decided to spend money on science – on basic science. Basic, pure, theoretical and experimental physics of high energies. Why? I do not know the social reason.

Peiris: You mentioned South Korea as an example of a country which encouraged science and technology. What do you see as the special factors that made South Korea recognize the need for science and technology?

Salam: Again, I do not know. I was in South Korea in 1978. For two days they had a conference on our subject. That was following a conference in Japan and they took advantage of a vast number of people being in Japan, to invite them over to Korea. On the plane I got a newspaper. The newspaper had a banner headline. President Park had made a declaration that day: "Korea's goal will be to beat China in science and technology." Imagine this as the goal set out for a small country like Korea trying to compete and beat China. But that was the sort of ambition that made Korea a science-conscious country. I don't think it happened overnight. Set your goal high and then work towards it.

The same was the case for Japan when the Meiji revolution took place towards the end of the last century. There were five articles in the constitution of Japan. The fifth article was "Knowledge will be acquired wherever it can be found." Knowledge meant science for the Japanese. The same thing happened in Sweden a hundred years ago. Can you believe that one hundred and fifty years back Sweden could not feed itself and had famines? It happened also in Russia. Lenin and then after that Stalin made it a part of Russia's state policy. And for Russia this was not new. "Science will be developed," Peter the Great decreed. In the conditions of today I am afraid science cannot be developed without state backing.

Peiris: I think it was Nehru's contribution that he had a sense of the "manifest destiny of India" and therefore this had to be buttressed by science and technology.

Salam: There is an interesting point here. Nehru was advised by Professor P.S.M. Blackett who was head of this department (department of physics at

Imperial College). Now Blackett was exactly opposed to my view. He thought the basic science was not needed in a country like India, that only technology was needed. He had his famous phrase: "There is a world supermarket of technology; go and buy in it." Therefore, Nehru did not set up any great scientific departments on basic sciences. He set up a number of national laboratories on the pattern of some in this country for applied work. Ever since there has been a continuing battle within India, within these laboratories, for getting basic sciences into them and in fact this is what has happened in India, in spite of the advice Nehru got. To take an example, the Atomic Energy Commission of India was headed by Bhabha. Bhabha had the same vision I am advocating. That man built up basic science as well as nuclear technology in his institutes.■

49

A Genius Called Abdus Salam

V.S. Venkatavaradan

Professor Salam visited India for 21 days and captured the public imagination. Following interview gives a glimpse into the creative mind of a great scientist. This is a partial text of the interview.

Question: *When did you decide to become theoretical physicist?*

Dr. Salam: When I went to Cambridge; it was my idea to get a tripos. Until 1948 I did mathematics. I had by then already listened to the lectures of Dirac and Pauli and I drifted more and more towards physics. In 1948, when I had finished my mathematics course, I still had one year's scholarship on and I had almost decided to do physics.

Fred Hoyle, my supervisor, said to me that if I wanted to become a physicist I must do experimental course; otherwise I wouldn't ever be able to look a physicist in the eye. "You follow me? In order to be able to do well in your future life," he asked. "Physics is experiment, not theory. Science is experiment. You Indians are very good at theory. You must, even if it kills you, take this last year for experimental physics." I told Fred Hoyle, "Sir, for the last four or five years I haven't done an experiment." "Never mind," he said, "you must do the experiment course." I finished the two years in one year.

Q. *At Princeton did you work with Einstein?*

Salam: Einstein was out of bounds for us, but still I had a long chat with him. From Princeton I returned to Lahore. It was at this time that I visited Bombay. Pauli was also in the city then.

I was the only theoretical physicist in Pakistan at that time. I therefore felt lonely – theoretical physicist has got to be able to talk, to discuss, to shout if need be. When Pauli came to Bombay he sent me a cable saying he was alone and wanted me to come and talk to him. So I took a plane from Karachi and a taxi to his hotel. I went up to his room and knocked. He told me to come in and without a word of greeting said: "Schwinger is wrong, I have proof for that."

Q. What was the feeling when you learnt that you had been chosen for the Nobel award?

Salam: I think one should realize that prizes are not something which you can merit for. They are God's gift. (According to *The New York Times* he is reported to have said: "My first reaction, of course, is the greatest gratitude to Allah who has guided our thoughts jointly in the way the truth lies in finding out the laws of nature.")

Q. Where were you when the prize was announced?

Salam: I was in London. It was at 12 o'clock that I received a telephone call. The Director General of IAEA, Dr. Eklund, happened to be a Swede and he himself was a member of the Academy. But he was not going to tell me about my getting the award until the actual announcement had been made. The first news I received was from Eklund's assistant. Then came the confirmation from Sweden itself. Immediately I drove to the mosque and did what is called *Namaz-e Shukrana*, the prayer of gratitude.

The *Newsweek* described it as "the research that represents an extraordinary achievement of the human intellect – a triumph of ideas which like politics, music and what have you should be part of human culture."

Q. What are the implications of your work for the layman?

Salam: Newton's unification had no practical significance for the layman for nearly three hundred years until the launching of the satellite; and mind you, Newton's unification was a tremendous feat – an intellectual tour de force.

Maxwell's unification, on the other hand, had the greatest practical significance for mankind in a mere ten years after the Scottish scientist's death. For instance it was found that a rotating electric charge produces magnetic forces – the radiation of heat and light, etc.

Now in our case also one may have to wait for three hundred years. One never knows – there is nothing that I can think of at the moment except that some people have suggested that our theory provides the *raison d'être* for what is called handedness of biological molecule. It is believed that the atomic potential is not left-right symmetric because of this interposition – because of the unity with the nuclear force.

Q. Do you believe in destiny?

Salam: I don't know what destiny is. All I can say is that I am continually being amazed at the depth revealed at each successive level we explore. I would like to quote to you a prediction which Oppenheimer made more than twenty-five years ago and which has been fulfilled today in a manner he did not live to see. "Physics will change even more. ... If it is radical and unfamiliar. ... We think that the future will be only more radical and not less, only more strange and not

more familiar and that it will have its own new insights for the inquiring human spirit."

Q. How would you comment on the view about the ultimate "unknowability" of the universe? And what about the despair which many eminent physicists have expressed?

Salam: My own reaction is totally different. I feel we should go to the limit of what we can do. We should not speculate and worry about not being able to do things. That I think was also Einstein's attitude (although he is believed to have said that God did not play dice with the world). Somehow the other, the idea of despair just does not enter my mind. As I had said earlier, my feeling is one of wonder.

Q. Is this sense of wonder that drives you on?

Salam: That's right. That is my inspiration. People have different sorts of driving forces. My colleague Weinberg has remarked in his book *First Three Minutes* that life is so miserable that the only thing which makes it worthwhile, is the charge given to us to indulge in the scientific endeavor to understand and to know.

We are reminded of Einstein's words that "the serious research scholar in our materialistic age is the only deeply religious human being."

Einstein defined religion as the discovery of the basic laws. He was deeply religious in the sense of wanting to discover the fundamental laws by which the Lord has created the world.

Q. What is your concept of God?

Salam: There are many concepts of God. For instance, there is the concept of God as the Law Giver. And there is the God of Moral Order. If you do well, the outcome would be good. And if you do evil, you will reap evil. Most of us believe in such things without ascribing them to God of Moral Order. Some people believe in a God of History, a God who controls history. Then there is the personal God to whom we pray.

Q. Could you describe your philosophy of prayer?

Salam: It is very difficult for a physicist to discuss prayer. I don't know what it does to you.

Q. What do you think of Sufism?

Salam: I am deeply interested in Sufism but do not claim to be a Sufi myself. My father is someone with direct personal experience. My father was a Sufi. If Allah grants me such experience I will be grateful. I doubt if physics can give any special perspective. All you can do is do physics as physics.

Q. Do you believe in ESP? A number of scientists and astronauts do.

Salam: No, I don't as a scientist. But if I get scientific evidence for such things tomorrow, I will believe in it. I am a product of purely empirical European – no, I should not say European – the scientific tradition is not confined to Europe; it is universal. That is why I respect Aryabhata. He was a real scientist. Al-Biruni was a real scientist with an absolutely rational approach.

Q. How was the Nobel ceremony like?

Salam: The Nobel Prize ceremony is a wonderful experience. For ten days we were the guests of the King and Queen of Sweden. In the first seven days, every day there was a party at which the main thing to do was to drink. They accommodate you in a hotel and all your expenses are paid for including breakfast; but they don't pay for lunch and dinner. Probably they feel that various parties to which you are invited take care of your needs.

The award ceremony is well rehearsed. On the day the awards are presented, the King and Queen wait for you and your arrival is announced with the blowing of a trumpet. When the trumpet sounds, you walk along and when it stops you also stop. Then there is a citation and then again the trumpet sounds. You receive the prize and bow to the King and Queen and walk back.

The winner of the prize for 1979 in literature was a Greek poet – Odysseus Elytis. When he came to Sweden, he was ill shod and he bought a pair of brand new shoes for the great occasion. As he walked up the smooth floors of the royal palace to receive the prize he slipped and fell.

I had taken my grand children. One of them who was just three years old started talking during the function. And his was the only voice heard in the royal hall during the function. Such a thing had never happened earlier because normally Nobel laureates do not take their children or grand children along with them when they go to receive their prizes.

Q. How many children do you have? Are they interested in physics?

I have five. The eldest, a girl, has a Ph.D. and is doing cancer research. But none of the others are interested in pure science except perhaps the youngest who is now little over five years old.

The other day he wrote to me: "Dear Daddy, do you know what is infinity plus infinity? I do. It is a big zero." Then he gave me some sort of an idea of plotting points in a circle – starting at a point in and returning to it. When I told him infinity plus infinity was very special, he was very reluctant to accept it. He said: "Three infinities are infinity but four are back to zero."

Q. Do you give him special attention?

Salam: I would like to. But he is so independent, so reluctant to accept any explanation.

That reminds me, the first research paper I wrote was literary – establishing the date on which the poet Ghalib changed his nom de plume. *The Illustrated*

Weekly once had rejected a short story I had written. But the *Weekly* did publish a short article in the early forties. I have forgotten the title; it was an adolescent literary effort.

Q. People say the receipt of Nobel Prize often signals the end of a creative career. If the recipient is a scientist, his work suffers on account of constant exposure!

Salam: That is absolutely right.

Q. Have you got to give up active research?

Salam: No, no. Look here, I am spending twenty-one days in India on this trip. I have never spent twenty-one days on anything like this before. And everybody tells me that it's very important that I should talk to people. It's incredible that I have spent a month already talking, preparing my lectures, etc. It's incredible strain.■

50

The Physicists that Changed the World: The Young Masters: Abdus Salam

C.P. Snow

Man of Letters, Author of *Two Cultures*,
London

If Einstein and Bohr were still alive, that great debate of theirs would take on another lease of existence. Theory has reached a climatic point – this is the present climax, and not the final one, of a series of revolutions which began in 1900 with Planck and his quantum of radiation, climbed up to the heights of Einstein and Bohr, consolidated itself with Dirac and Heisenberg, as always in science drawing in many minds along the way, and is now expressed by Gell-Mann, Ne'eman, Salam, and a dozen others.

Those who have contributed to this intellectual edifice – it is not a rhetorical flourish to say with a cool mind that it is the major intellectual achievement of our century, and will be so regarded by our successors – have come from nearly all countries, different forms of society, different ethnic stocks. The names in this account tell their own story. There have been Americans, Russians, Germans, French, Italians, British, and Japanese. A statistically disproportionate number are of Jewish origin.

There is someone who ranks with the most eminent who should be mentioned. This is Abdus Salam who has over the past twenty-five years been a leader in the theoretical developments [in Physics]. Salam was born in a peasant home in a Pakistani village. He managed to get a place in the government college at Lahore. Conceptual and mathematical ability is easy to detect at a very early age, and in Salam's case some enlightened administrator apparently did so. After Lahore, he was dispatched to Cambridge, studied with Dirac, and since then has had a creative career of continuous brilliance.

He is a citizen of the world and has devoted much of his influence and energy to help educate young scientists who come from provenances as underprivileged as his own. To this end he established the International Centre for Theoretical Physics, an institute which has its home in Trieste, thanks to the goodwill of the Italian authorities, and Salam has vigorously commuted between the Adriatic and his home and professorship at Imperial College in London. The

From *The Physicists: A Generation that Changed the World*, by C.P. Snow.
London: Papermac, 1982, pp. 149-50.

Centre has had many successes in developing the progress of scientists of all races. Few men have done more good than Salam for the talented poor.

It happens that Salam is a devout Muslim, believing passionately in the highest axiom of Islam, the essential brotherhood of man. It is good for us to be reminded that men like Salam can translate this axiom into action.

Incidentally, Salam is probably the only committed religious believer, in the doctrinal sense, among all the great theoreticians. Many have had deep religious feelings, as Einstein had, but couldn't accept any creed or belief. Most were reverent in the face of nature, had their own personal morality, sometimes a piety towards the religion in which they had been brought up, but in which they ceased to find meaning. But Salam is, in the full sense, a religious man.■

51

How I discovered SU(3)

Yuval Ne'eman
Professor Emeritus,
University of Texas, Austin

I arrived in London at the beginning of 1958. I wanted to study (general relativity) which had attracted me as a student, and found out that the place for that was King's College, with the astrophysicist Bondi.

However this institution was located in a region of high traffic, and I soon realized that it would be quite impractical to work at the embassy in the west of London, and study at a college in the east of the city. So I settled for Imperial College, which was a five-minute walk from the Embassy.

My choice of a supervisor for my thesis was somewhat incidental. I consulted the College prospectus and approached one of the professors whose name appeared under 'Theoretical Physics'. I told him about my interest in Einstein's unified field theory, to which he replied that he did not know if anyone was still working on that, but Abdus Salam and his group in the Mathematics Department were working on field theory.

I came to Salam, presenting the only letter of recommendation that I had, which was from Moshe Dayan. Salam laughed and commented: "What can a General know about scientific abilities."

Nevertheless he agreed to take me on probation, on the strength of my degree from the Technion-Israel Institute of Technology – and the recommendation letter.

I had missed the first term, and had to absent myself from some lectures in the second term too, when my duties as a defense attaché interfered. Eventually in May 1960 I resumed my studies with the status of an officer on leave with a one-year scholarship from the Government.

I was captivated by group theory, which I had first met in Salam's course. I learned group theory from a textbook by A.B. Dynkin, translated from Russian. It was Salam who suggested that I should study Dynkin's work. He understood that I was interested in classifying the particles and finding their symmetries, when on the basis of my rather scanty knowledge of group theory I began to suggest possible models in this area.

When I first showed him my suggestions, Salam told me that they had

Excerpt from Yuval Ne'eman's book *The Particle Hunters* (Cambridge: Cambridge University Press, 1986).

already been attempted five or six years previously. My next proposals, he told me, had been suggested by others two or three years before. I felt that I was getting nearer to the present. However, Salam was skeptical.

He proposed another subject, and when I insisted on trying to classify the hadrons he said: "I wanted to assign you an easier problem, on the assumption that it would be better for you to produce a complete work during one year of leave from the army. However, since your mind is made up, do it your way, but you should know that you are embarking on a highly speculative search. If indeed you have already decided, at least do it properly. Learn group theory thoroughly."

So he recommended Dynkin book. I learnt Dynkin's work and was now able to define what I was looking for: a rank two Lie group which would permit the classification of hadrons according to isospin and strangeness, in a manner that would fit the properties of the observed particles. I found that only four groups might do the job, and began to examine each of these separately.

I remember that one of them (called G_2) yielded diagrams in the shape of the Star of David, and I hoped that it might be the correct one – but it was not. On the other hand $SU(3)$ gave a perfect fit.

I finished my work in December 1960, and discussed it with Salam. I then submitted a paper for publication early in 1961, and it appeared shortly after.

52

Abdus Salam

Rushworth M. Kidder
Staff Writer, *The Christian Science Monitor*,
Philadelphia, USA

The International Centre for Theoretical Physics perches on a pine-covered slope overlooking the sapphire-blue Adriatic. But the director's office looks out the back into the side of a hill. The location seems somehow in character for Abdus Salam, whose purpose lies less with elegant vistas than with little-known corners of the world – and who, despite his Nobel Prize for Physics, typically describes himself as “a humble research physicist from a developing country [Pakistan].”

Asked about his agenda for the next century, he responds without hesitation. “The real issue, to my mind,” he says, “is the great divide between the South and the North,” referring to those regions of the globe roughly representing the developing and the developed nations.

Although he speaks softly – from a desk chair facing a framed photograph of Albert Einstein and a blackboard chalked with mathematical formulas – his words carry fervor.

This “great divide” between the developing world and the industrial nations, he explains, arises from the fact that each side has a completely different set of problems. The major 21st century issue facing the North, he says, is the arms race and the threat of nuclear warfare. The problem facing the South is the threat of starvation and utter poverty.

Picking up a copy of *Ideals and Realities*, a collection of his essays, he turns to a piece he wrote about Al-Asuli, an 11th century Islamic physician. Al-Asuli, he says, divided the problems of humanity into diseases of the rich and diseases of the poor.

If Al-Asuli were alive today, Dr. Salam says, he would make the same distinction. “Half his treatise would speak of the one affliction of rich humanity – the psychosis of nuclear annihilation,” he says. “The other half would be concerned with the one affliction of the poor – their hunger and near starvation. He might perhaps add that the two afflictions spring from a common cause – the excess of science in one case and the lack of science in the other.”

Reprinted from *The Christian Science Monitor*, 1986.

For Salam, the operative word here is "science" – which he is careful to distinguish from "technology", or the application of scientific knowledge to human problems. One great difficulty for the developing world, he explains, is the misplaced assumption that sharing the latest in Western machinery, communications, and transportation – technology transfer – will be a panacea for the South.

"Technology transfer is something the South has asked for," Salam says, "and the North is resisting. Quite rightly. I don't blame [the North] for one second for not giving technology as such. Why should you? Why should anybody part with things that nobody else has helped to create?"

"That's where the bread and butter is concerned," he adds, referring to the central role that the sale of technology plays in the economies of the industrial nations.

Instead of technology transfer, Salam says, the South in the coming century should be asking for a transfer of the basic science out of which technologies can spring. "I wish that the North could decide to give the South as much science as possible. Why this insistence on science?" Because "science is the basis of technology in the present day." He cites the case of Japan. Over the years the Japanese invested heavily in learning "all of science at a very high level. And then they were really successful in their technology."

Similar things are beginning to happen, he says, in five of the developing nations: Argentina, Brazil, China, India, and South Korea. He is especially impressed by the latter country, which he recently visited.

"They took me straight away to the television studio – two and a half hour long interview," he recalls, "in which they said, 'We have made it a national objective to win Nobel prizes. Can you give us advice?'"

"I told them they were being silly," he says with a chuckle, adding that "they may or may not get Nobel prizes." But he notes with approval that "the very fact that they made it a national objective is a very important thing. That means that they will stock up their libraries, they'll get scientific literature, they'll fund a lot of fellowships, they'll do everything possible to make themselves into a scientifically advanced country."

And that, he suggests, will do more for South Korea than any amount of reliance on Western technology.

As he looks forward into the 21st century, Salam distinguishes several kinds of science that will be practiced. The first he calls "science for science's sake" – the most basic and theoretical research, producing discoveries that sometimes go unappreciated for decades. In general, he says, such research is "probably in a healthy state," despite the never-ending battle to pay for it.

No Science for the Poor

"Then there's science for man's sake," he says, a category he breaks down into three parts: "global science, science for the rich countries, [and] science for the poor countries."

"Science for the poor doesn't exist, simply doesn't exist," he laments – although he notes that the poor countries have plenty of problems that science could help resolve. He cites the current medical concern over AIDS (Acquired Immune Deficiency Syndrome): "As long as it remained in Haiti, nobody ever bothered about it." Now that it has come to Europe and America, "it will get the attention it deserves."

"It always deserved that attention," he adds wryly.

And what about science for the rich countries? That, he says, gets entangled in defense spending – which, he says, accounts for half of all research spending in the developed world.

For Salam, in fact, the real threat of the nuclear arms race is not that it might cause ultimate holocaust. It is that swelling defense costs will sap resources needed to combat the rest of humanity's problems. It's a line of argument, he says, elaborated by President Dwight Eisenhower. "Eisenhower [made] it very clear that every single B-52 bomber that is made in America is depriving not only the poor in the Third World, but also Americans, of sustenance, of shelter, of aid."

"If Eisenhower were alive, he would be just aghast" at current levels of defense spending and the lack of attention to the developing world. Referring to massive defense spending in the North and developing world poverty, Salam says: "Unless you are conscious that the two problems are connected, and that [the developed nations] are squandering the wealth of this world – not only the wealth of this world but also the time and the energies of its scientists and its technologists, which could be used toward bettering humanity – you'll never get to grips with" the basic challenge facing the 21st century.

But what about the peacetime spinoffs that arise from defense-based research? "The statement that defense expenditures have 'fallout' is rubbish, total rubbish," Salam says flatly. "And the statement that since you invest in 'star wars' you will do your toothpaste better is [also] total rubbish."

What's really needed, says Salam, is not the 'fallout' from defense projects but a concentrated effort to study some of the developing world's most pressing problems – starvation, for example. Although Salam supports the idea of food aid for developing nations, he sees it as only a "short-term business". The root of the problem is "food deficiency, drought, and desertification".

The Basic Problem

"This is the basic problem to be solved scientifically," he says. But across much of the developing world, he points out, "there are no scientific studies at all

of climate [and] of the underground water situation in the deserts – whether there are underground lakes, and so on.” The lack of such studies – which are common enough in the developed countries – supports his contention that “science for the rich” is something quite different from “science for the poor”.

One problem in conducting such studies, however, is that they frequently transcend national boundaries.

For that reason, they fall under Salam’s third heading of “global science” – the study of the largest interdisciplinary and international issues concerning the global environment.

On this point, he expresses profound pessimism. “There’s no such thing as global science as a subject,” he complains. Even the disappearance of rain forests, which is commanding increased public attention, is not being considered in global terms.

“People do not take [the rain forest] as a global asset,” he laments. “People take it as a problem of Brazil, a problem of Malaysia. How many governments are willing to spend money on that sort of thing? None. Zero.” The problem is the lack of “the scientific infrastructure to look at the global problems.”

“Everybody seems to be for himself,” he says sadly. “There is no global vision at all. It’s the lack of global vision that worries me, really. It’s the issue of globalism which is missing in science, which is missing in the food problem, which is missing in the health problem.” What is needed is “a vision of a sort which I don’t see any statesman having.”

From his position as an administrator, Salam says he clearly sees the need for sources of funding that would encourage such globalism. He adds that such funds, if they are to come, will have to come from the developed world.

But he again rejects as “rubbish” – one of his favorite words – the idea that “if you save funds from nuclear [arms limitation] you will put them into the welfare of humankind.” The temptation, he says, will be for rich countries simply to funnel the savings back into tax relief – “making the rich richer and the poor hungry man’s soul sink lower”.

“The whole attitude has to become very different,” he notes.

Why Turmoil Could Spread

And if the “great divide” between the rich and the poor nations is not closed? Salam says that it will be increasingly “hard to ignore [the developing countries’] problems in the 21st century” for two reasons.

First, he says, the North will no longer be able to “insulate itself” politically from the South. If the gap is not narrowed, he says, “What will happen is what is happening already in the Third World” – turmoil, military governments, unrest, and “people on top of each other.”

Second, he notes that the world-wide environment “may be affected by lack of attention to the global problems and to scientific globalism.”

"In that sense," he says, "no parts of the world are going to be safe from the feeling of turmoil. At the moment, it doesn't [seem to] affect Americans to have starving Africans at their hands. They may very well say, 'Well, if they want to starve, let them starve.'"

"But I don't think man lives like this," he says. Speaking of rock star Bob Geldof's efforts to raise money for African famine relief, he says, "I think the Geldofs of this world make their point when they show what can be done in a small way."

What, then, does he hope will close the gap? He would like to see industrial nations "specialize" in providing the scientific training to elevate the developing nations. "For example, higher education may be taken up by Britain and the United States. The Russians may take up lower education. The Japanese and the Germans will be asked to do technology."

"That," he concludes, "will be my vision of the future."



62. Some Postage Stamps Honoring Abdus Salam

53

A Review of the Italian Edition of
Abdus Salam's *Ideals and Realities*

It is difficult to find pages as vibrant with human warmth, religiousness, political and moral duty and scientific depth, as in a recent collection of articles (larger than the English edition) of Abdus Salam "Servant of Peace", which is the literal translation of his name, entitled *Ideals and Realities* (Trieste, Italy: Edizioni Lint). Perhaps the *Thoughts of the Difficult Years of Einstein* may be able to produce the same emotions in the reader.

Having to say it schematically, one may say that the Physics Nobel Laureate Salam is at the same time two persons who combine only rarely; but when they do, they produce a miracle of humanity. Abdus Salam is a scholar and a sage. As a scholar, that is, as a scientist, he is the last great follower of an ancient tradition of physicists, for whom the intellectual scope of science is the unification of the laws of nature consisting of a few principles, to a grand unification of only one principle. In this search of the "arche", which began in Greece, and continued in Islam (Al-Biruni sustained that Nature had the same laws everywhere, on Earth as on the Moon), and materialized with the encounter of these two civilizations beginning with modern science, from Galileo to Einstein, Salam has made a fundamental contribution with the electroweak theory for which he received the Nobel Prize in 1979.

As a sage, Salam is again two things: he is a man profoundly religious who finds in the Qur'an the justification and the best reason for his scientific work, and he is a politician, in the highest and noblest sense of this degraded term, who places all his energy in improving the living conditions of the Third World. Whoever has had the opportunity of meeting him and listening to him, knows that he often refers to poets and to the Holy Book in order to give strength to his ideas.

A verse of Omar Khayyam, which Salam often cites gives an idea of the commitment of Salam, the man of action:

Ah love! Could thou and I with fate conspire
To grasp this sorry Scheme of Things entire
Would we not shatter it to bits – and then
Re-mould it nearer to the Heart's Desire. ||

Review published in *Corriere della Sera*, August 6, 1986, of the Italian translation of the first edition of *Ideals and Realities* (*Ideali e Realta*, translated by Vincenzo Gatti, published by Edizioni Lint, Trieste, 1986.)

54

Introduction to Abdus Salam's *Renaissance of Sciences in Islamic Countries*

M.H.A. Hassan
and Hassan Dalafi

"Men like Abdus Salam do not belong to any community or country. Their place is amongst the most brilliant in the world and therefore they belong to the entire humanity. In my opinion, wherever Abdus Salam has the facilities for work he should stay there and Pakistan should help him stay there. His personal gain or the gain to his family or to his country would be insignificant as compared to the gain to science to which he is devoted and the advancement he makes will benefit all human beings whichever country they may be living in."

Truly Prophetic! Addressed to Ch. Muhammad Hussain, Professor Abdus Salam's father, in June 1951 by Mian Afzal Husain, Vice-Chancellor of the Punjab University, the words came true not much later. As a physicist, Salam moved ahead of the wave, embedding half a dozen notions in omnibus papers – to win the Nobel Prize in 1979, the first (and so far the only) Muslim ever to receive the Prize in the sciences. The Prize signified much more than a personal triumph: as the only living developing country national with a Nobel Prize in the sciences, he symbolized the upsurge of scientific enquiry in Third World countries.

Salam won the Nobel Prize for his theory of unification. "Until two decades ago," he explained to a group of academics and the country's President at the University of Islamabad (Pakistan) just after the award, "physicists believed that there are four fundamental forces of Nature; the gravitational, the electromagnetic and the two nuclear forces, the weak and the strong. Two decades ago, my colleagues and I suggested that there were indications that the weak nuclear force was not really different from electromagnetic and that the two could interconvert, one into the other. We were searching for a unity, in the tradition of Newton, Maxwell and Einstein and the unified theory was formulated

From: *Muhammad Abdus Salam: Renaissance of Sciences in Islamic Countries*, edited by H.R. Dalafi and M.H.A. Hassan, pp. vii-xiii. Singapore: World Scientific Publishing Company, 1994.

in its final form in 1967, at Imperial College, London, and the International Centre for Theoretical Physics at Trieste with which I have the privilege of being associated, and also independently at Harvard. The fact that we were seeking a unity among the seemingly disparate forces of nature, is part of our faith as physicists and of mine as a Muslim. Just eight days back, I was asked to reply on behalf of the physics Prize winners to the Banquet address of His Majesty the King of Sweden in the great and glittering Banquet Hall of Stockholm. With your indulgence, I shall read out part of what I said, for it bears on this faith in the ultimate unity and symmetry of Nature. "The creation of physics is the shared heritage of all mankind. East and West, North and South have equally participated in it. In the Holy Book of Islam, Allah says: "Thou seest not, in the creation of the All-Merciful any imperfection. Return thy gaze, seest thou any flaw. Then return thy gaze, again and again. Thy gaze comes back to thee dazzled, aweary." This, in effect, is the faith of all physicists; the deeper we seek, the more is our wonder excited, the more is the dazzlement for our gaze. I am saying this, not only to remind those here tonight of this, but also for those in the Third World, who feel they have lost out in the pursuit of scientific knowledge for lack of opportunity and resources." This was the first time that the Holy Book was recited in the Banquet Hall of Stockholm.

Salam's second achievement – that of providing a rendezvous for developing-country physicists – came earlier in 1964 with the establishment of the International Centre for Theoretical Physics in the idyllic surroundings of Trieste, Italy.

These accomplishments on two fronts – physics and nurturing science in developing countries – have won accolades for Salam. In the words of Professor J. Song, State Councillor and Chairman, State Science and Technology Commission, China, Salam's "wholehearted devotion to the promotion of science and technology in the Third World countries, first reflected in the founding of the International Centre for Theoretical Physics and, more recently, in the initiative of setting up the Third World Academy of Sciences and its affiliated organizations, has won admiration from all over the international scientific community. An internationally renowned scientist who was born in a Third World country, who is dedicating his life to the development of science in the Third World countries, and who has won honor for the Third World, you, of all others, will always be respected as a pioneer in attempting to narrow the gap between the industrialized countries and the developing countries in science and technology."

Yet, all through the years, Salam has nursed a passion for the rejuvenation of science in the Islamic World – once a bastion of innovation and creative impulse – as the papers appearing in this volume show. They are based on lectures delivered by Salam in various scientific meetings and fora to review the state of science in the Islamic countries and to suggest measures for its improvement.

The papers convey the simple message. The Muslims have a scientific past in accordance with the commandments of the Holy Book and the Prophet of Allah. It is their religious duty to strive for a scientific future.

Salam is intimately familiar with the golden era of Science in Islam and contends that modern science is not a creation only of the Western, Judeo-Christian tradition as is often claimed – but that contemporary scientific advances have their roots in innovations and discoveries made earlier in Islamic lands. In making the claim, he is neither argumentative nor contentious but rational and scholarly, quoting extensively from eminent historians and researchers. Thus, we have Robert Briffault testifying, “The Greeks systematized, generalized and theorized, but the patient ways of detailed and prolonged observation and experimental inquiry were altogether alien to the Greek temperament. ... What we call science arose as a result of new methods of experiment, observation and measurement, which were introduced into Europe by the Arabs. Modern science is the most momentous contribution of the Islamic civilization.” These thoughts are re-echoed by George Sarton, the great historian of science: “The main, as well as the least obvious, achievement of the Middle Ages was the creation of the experimental spirit and this was primarily due to the Muslims down to the twelfth century.”

Salam quotes Charles Singer who contests the Eurocentrism of Western historians in *History of Technology* and makes the observation, “Europe, however, is but a small peninsula extending from the great land masses of Afrasia. This is indeed its geographical status and this, until at least the thirteenth century AD, was generally also its technological status.” In skills and inventiveness during most of the period 500 to 1500 AD, Singer continues, “the Near East was superior to the West. For nearly all branches of technology, the best products available to the West were those of the Near East. Technologically, the West had little to bring to the East. The technological movement was in the other direction.”

Salam, however, does not confine himself to a study of the Islamic past. He talks of the present and the future and poses the following question to contemporary Muslims: “The 20th century has been a century of great synthesis in science – the syntheses represented by quantum theory, relativity and unification theories in physics, by the Big Bang idea in cosmology, by the genetic code in biology, by the ideas of plate tectonics in geology; likewise in technology, the conquest of space and the harnessing of atomic power. Just as in the 16th century when the European man discovered new continents and occupied them, the frontiers of science are being conquered one after another. Do you not feel as passionately as I do that our men in Arab-Islamic lands should also be in the vanguard of making these conquests?”

The exhortation is not an exercise in rhetoric. Salam suggests practical steps for rejuvenating the “Islamic Commonwealth of Science” and gives the blueprint for the establishment of an “Islamic Science Foundation” to “turn the pages of

history back and again lead the world in the sciences". He appears convinced that "it does not need more than a decade of enlightened science policy to bring about a wholesome change. First and foremost, our society – and here, I include our young men and women, their parents, their career-advisers, their teachers and our merchant-princes – must develop a commitment to the scientific enterprise, a commitment like the one which was recently developed in Japan, USSR, India, China and South Korea. This will happen when our ministers and princes undertake generous patronage of sciences, and our industrialists and our agriculture entrepreneurs begin to believe that there is a profit in science and technology – particularly on science-based high technology." The renaissance of sciences within an Islamic and Arab Commonwealth, according to Salam, is contingent upon five cardinal preconditions: "passionate commitment, generous patronage, provision of security, self-governance, and internationalization of the scientific enterprise."

Salam firmly believes that the laws, traditions and modalities of science are universal and deprecates the diversionary slogans of "Islamic" ("Christian" or "Buddhist" or "Hindu") science. He contends that "Islamic Science is a slogan with no meaning". To some, it may mean that Islamic ethics should be applied to science. "But Islamic ethics are universal anyway – care for the environment, lack of specialization, care for wholeness and so on. To call this Islamic science is an absurdity." He also maintains that science and faith can live in harmonious complementarity.

Elaborating on this point, Salam explains, "Unfortunately, some of us Muslims believe that while technology is basically neutral, and that its excesses can be tempered through an adherence to the moral precepts of Islam, science – on the contrary – is value-loaded. It is believed that modern science must lead to 'rationalism', and eventually apostasy; that scientifically trained men among us will 'deny the metaphysical presuppositions of our culture'. Leaving aside the fact that high technology cannot flourish without high science and also leaving aside the insult to the 'presuppositions of our culture' for implied fragility, I believe that such an attitude towards science is a legacy of the battles of yesterday when the so-called 'rational-philosophers' with their irrational and dogmatic belief in the cosmological doctrines they had inherited from Aristotle found difficulties in reconciling these with their faith."

Lamentably, the current state of science in the Islamic World, which embraces almost a fifth of humanity, leaves much to be desired. The miniscule investment in indigenous research and development is indicative of the low priority generally accorded to science.

Citing recent figures, Salam laments the frail base of Science in Islamic world today: "Around 45,000 research and development scientists within the Islamic World (as given in the Background Paper submitted to the first meeting of the Science Commission of the Organization of Islamic Conference during

May 1983) compared to one-and-a-half million in the USSR and four hundred thousand in Japan ... an analysis of these and similar figures reveals that as far as physics is concerned, the Islamic community is around one-tenth in size and one-hundredth in scientific creativity in research publication compared to international norms." Salam quotes Francis Giles writing in *Nature*, "Some of the Islamic states are busy fighting wars which cost billions of dollars – no doubt they have little time for science. Trade structures are dominated by imported technology and most countries have economic and scientific systems geared to imitation rather than originality."

Also included in this book is a 1977 memorandum signed by Arab physicists visiting the International Centre for Theoretical Physics in Trieste addressed to "a few chosen men in high positions of scientific, cultural and educational leadership" to create a fund "for increased participation of Arab scientists in activities at the Centre and for regional activities, like winter colleges and conferences, organized in collaboration with the Centre. The latter are particularly important as a prelude to the realization of an independent Arab Physics Centre in the future." Regretfully, the response to the memorandum has been, and still remains, one of complete indifference.

This "zero patronage" of science evokes Salam's deepest anguish. "The Arabs have been building palaces, but no palaces of science." They "will talk of fighting the West, but no one talks of science". What is particularly appalling is that the science communities are not self-governing and are "run by bureaucrats – not scientists" who "frown at internationalism", an attitude typical of most Islamic states. No wonder that "of all civilizations on earth, the Islamic – both Arab and non-Arab – is the weakest in science today."

It is painful and agonizing that Salam's sustained strivings for the promotion of science in Islamic countries have remained largely unheeded. His passionate pleas in interviews with the Islamic Heads of State have elicited verbal support but no action. His quest for a twentieth-century Haroun-ur-Rashid who could put on the mantle of a Patron Saint to nurture science in the Islamic World remains an elusive dream.

Mirroring deep frustration, his recent Faiz Lecutre at Lahore, Pakistan, ended on a pessimistic note. Salam cited the example of Sir Syed Ahmad Khan, the great educationist among the Indian Muslims, who showed enterprise and courage in imparting English education to the Muslims. Sir Syed was opposed by the orthodox diehards who loathed English education. Driven to desperation, Sir Syed ultimately had to say: "You may disown me, you may call me an infidel – a *Kafir* – but allow me to educate the nation's youth for the sake of the future just as you allow a non-Muslim mason to build a holy mosque." In the mould of Sir Syed, Salam repeated Sir Syed's plea and suggested that he too would be content with the status of a non-Muslim mason building a holy mosque.

One of Salam's papers begins with Alfred North Whitehead's words: "In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed. Today we maintain ourselves, tomorrow science will have moved over one more step and there will be no appeal from the judgement which will be pronounced ... on the uneducated."

We end this brief recital of the world of the greatest scientist in Islam since Ibn al-Haitham and Ibn Sina with the above words.■

Trieste, Italy
July 8, 1988

55

Science Sublime:
Abdus Salam, Theoretical Physicist

Lewis Wolpert and Alison Richards

The Greeks wished to explain all the phenomena of Nature in terms of four elements: fire, air, earth, and water. Modern science takes the urge to simplify still further. One of the most exciting and romantic endeavors of the twentieth century is the attempt to show that what we now know to be the four fundamental forces of nature – gravity, electromagnetism, and the strong and weak nuclear forces – are aspects of a yet more basic principle. This is the province of the particle physicists, the theoreticians and experimentalists who are concerned with the behavior of electrons, protons, and the host of other subatomic particles that make up matter. It is a formidable undertaking.

The two forces with which we are most familiar are gravity and electromagnetism. At the beginning of the nineteenth century electricity and magnetism were thought to be quite distinct, and it was the work of Michael Faraday and, later, James Clerk Maxwell which showed that they were basically two aspects of the same phenomenon. Maxwell's four equations provide a complete description of the production and interrelation of electricity and magnetism, and subsequently led to the development in this century of what are known as the gauge theories. Gravity was, of course, first recognized by Newton, and shown by Einstein in his General Theory of Relativity to be an expression of the curved geometry of space and time. Einstein tried until the end of his life to unify electromagnetism with gravitation but, like everyone since, failed to do so.

The recognition of the existence of two more fundamental forces – the strong and the weak nuclear forces – came with the discoveries about the structure of the atom in the first decades of this century. It became clear that an atom is not an indivisible sphere like a billiard ball, but consists of a small central region – the nucleus – surrounded by a cloud of particles called electrons. The nucleus itself is composed of particles called protons and neutrons, which are bound together by the strong nuclear force. But atomic nuclei are not always stable. During certain kinds of radioactive decay, for example, the neutrons are transformed into protons, electrons, and elusive particles called neutrinos. Transformations of this kind are governed by the weak nuclear force.

Opening chapter of *A Passion for Science*, by Lewis Wolpert and Alison Richards. Oxford: Oxford University Press, 1988, pp. 13-23.

In the late 1950s Abdus Salam began to address the problem of unifying the weak force and the electromagnetic force. On the face of it, the two forces are very different. One, the electromagnetic force, is a long range force which can be felt at almost any distance. The other, the weak nuclear force, is a short range force acting over unimaginably short distances. But Salam succeeded. In 1979, together with Steven Weinberg and Sheldon Glashow, he was awarded the Nobel Prize for physics. Their work was mathematical and theoretical, but predicted that certain, as yet undiscovered, particles should exist. It was only in 1983, under the cosmic conditions created in the huge particle accelerator at CERN that these particles were detected, and the theory finally confirmed. [...]

I interviewed Salam at his home in South London. We could hear children playing in the next room and the familiar sounds of domestic life in the background. I could not help but be aware of a contrast between the sheer ordinariness of our surroundings and the intellectual reach of the ideas we were to discuss. Yet in his life, as well as in his research, Salam is able to accommodate seemingly disparate elements with ease: the familiar and the arcane; a commitment to physics in the developing world and to his own work on unification; to science and to Islam. I wanted to learn something of the route which had brought him from a peasant community in Pakistan to international acclaim in particle physics. [...]

“When you got to Cambridge did you become immediately involved in theoretical physics?”

“No, I started in mathematics because I had the mathematical background but, slowly and gradually, during the two years in mathematics I shifted over to theoretical physics. Dirac was lecturing at that time and I attended his lectures. Then I still had a third year free in the sense that I had the scholarship and the choice of whether to go on with higher mathematics – that’s Part III of the mathematics tripos – or to do the physics tripos. One of my teachers was the astronomer Fred Hoyle, and I went to ask Fred his opinion about this. He said ‘If you want to become a physicist, even a theoretical physicist, you must do the experimental course at the Cavendish. Otherwise you will never be able to look an experimental physicist in the eye.’ And that was very correct advice. But it was a hard year for me doing experimental work at the Cavendish, not having done any for so long. It was the hardest year of my student days.”

“What did you find so hard about it?”

“The whole attitude towards experiment. It’s very interesting. In the Cavendish there used to be a tradition that you were not given any fancy equipment. Just string and sealing wax. You were given every discouragement and you had to overcome this. Now, the very first experiment I was asked to do was to measure the difference in wave length of the two sodium D lines, the most prominent lines in the sodium spectrum. I reckoned that if I drew a straight line

on the graph paper then its intercept would give me the required quantity I wanted to measure. As you know, mathematically a straight line is defined by two points and if you take one other reading then mathematically that should be enough since you then have three points on that line, two to define the straight line and the third one to confirm. So I spent three days in setting up that equipment. After that I took three readings, and I took them to be marked. In those days the marking of experimental work in the class counted towards your final examination. Sir Denys Wilkinson, who is now Vice Chancellor of Sussex University, was one of the men who supervised our experimental work, and I took it to him. He looked at my straight line, and said 'What's your background?' I said 'Mathematics'. He said 'Ah, I thought so. You realize that instead of three readings you should have taken one thousand readings and drawn a straight line through them.' I thought I'll be damned if I can go back and face those three days again. I had by that time dismantled my stuff and I didn't want to go back. So I tried very hard to avoid Sir Denys Wilkinson – he wasn't Sir at that time – during the rest of the year.

"I still remember the day the results came out in 1949. I was looking at the result sheets hung in the Cavendish and Wilkinson came up behind me. He looked at me and said 'What sort of class have you got?' and I very modestly said 'Well, I've got a first class.' He turned full circle on his heel, three hundred and sixty degrees, turned completely round and said 'shows you how wrong you can be about people.' But going back to Fred Hoyle, I think his advice was absolutely right."

"Now you got the Noble Prize for unifying certain parts of the theory in particle physics. How did you get the idea?"

"It's such an *attractive* idea. You see, the whole history of particle physics, or of physics, is one of getting down the number of concepts to as few as possible. And when you are doing this 'getting down' it seems absolutely the natural thing. In fact, it always surprises me that some of my physics friends – and some of them very eminent people, Nobel Prize winners – would not subscribe to the idea. They would find the difficulties in uniting two totally disparate looking phenomena so overwhelming that they would think you stupid to think otherwise."

"Do you think your religious views made you think that they could be unified?"

"I think perhaps at the back of my mind. I wouldn't say consciously. But at the back of one's mind the unity implied by religious thought perhaps plays a role in one's thinking."

"Steve Weinberg came to the same theory quite independently. That's surprising isn't it?"

"Not at all. The ideas in our subject are common and the diffusion of ideas is astonishingly large. Everybody knows almost everything of what's going on. I think it's a result of the system which we have developed of Summer Schools and symposia, and of course, the pre-print system. It's a very efficient system and we in theoretical physics are probably the best organized for that, for some curious reason. Although, mind you, at the time that Steve and I were working on the theory we were using ideas which, although they had been published, were not highly regarded. In that sense we had the field more to ourselves than would be the case today."

"Did the people accept the theory at once?"

"No, not at all. The theory was elaborated in 1967 and it was completely ignored. In fact, even before that, when I took another paper – one I wrote in 1964 – to be published in a journal the editor said 'The thing that you are predicting has already been tested and not found. Will you add the words that this paper is purely speculative?' And I had to, in order to get the thing published. Those experiments were wrong, the ones which he was alluding to, but we only found that out later."

"So how did the theory come to be accepted?"

"As I said, the theory was elaborated in 1967. There was a young physicist called t'Hooft, a Dutchman, who played a very crucial role in showing that the theory was mathematically well established. It was his first piece of work, at the age of 25 or so, and it gave the idea more respectability among the theoreticians. That was in 1971. Then in 1973 the experimenters redid those experiments which had previously shown that our ideas were not correct. They were redone properly at CERN and that gave the first indication that the theory was on the right lines. But then the experiments were repeated in the United States and they contradicted the Geneva results. And it went on like that for a couple of years, back and forth between the experimenters."

"It's interesting that those experiments turn out to be wrong. As an outsider one thinks that the one thing you have that is reliable in physics is the experimental data. I'm surprised that the facts are so often wrong."

"Well, you see, take one experiment which is going on now and which concerns the next stage of unification. I said we have united electromagnetism with the weak nuclear force. But there's a second nuclear force, the so-called strong nuclear force, and that is not yet united with the electro-weak force. We hope it will be, and most of us would like to believe that it is happening. The crucial experiment for this is the decay of the proton. The proton is supposed to be, or was supposed to be, before this theory came along, a fundamentally stable particle. This theory says no, in 10^{32} years all protons will decay. That's a very, very long time. The life of the universe as you know is 10^{10} years. So in 10^{32} years – my goodness – every proton will decay! Now to see this experimentally

you need 10^{32} protons to be watched for one year before one of them will decay. At the present time the situation is that there is an Indian experiment, 7,000 feet deep in the Kolar Gold Field mines, which claims to have seen three events of proton decay. There is the experiment in Japan which claims to have seen one event and there are much more statistically significant experiments in the United States which claim to have seen none. Now what do you believe? The experiments are very difficult. I don't know which way the camel will sit, but this is a crucial experiment. And so it's perfectly possible that some of the experiments are wrong, or that their interpretation is wrong, and that we have to wait for more statistically significant signals."

"Now, you are a theoretician, so you're sitting there, rather grandly, while these experimentalists are testing your theories. But for the people doing the experiments with these big machines life is rather different. The papers they publish have fifty, even a hundred, authors. Do people mind that?"

"I think many experimental physicists do not like this situation. Many of them would rather have the old days when just one man or two or three people collaborated and did an experiment and enjoyed it. But the nature of the beast is now such that you cannot help it. You have to have large collaborations because the experiments are costly, and they need vast quantities of equipment. For example, one hundred and fifty experimenters were associated with the two experiments at CERN which finally showed the validity of our theory. And the equipment is incredible. The detecting devices are three storeys high."

"Is your field a very competitive one?"

"Oh yes. The practitioners number of the order of about five thousand in theory and about the same number in experiment. And then there is a premium on youth as you know very well."

"Why? Do you just think you're better when you're young?"

"No, you are less encumbered. You don't live with your past. You don't live with your failures. You are much more willing to try more ideas in a different way. Older people are also, of course, more encumbered with various types of administrative duties in order to keep the subject running and that sort of thing. But I think most of all it's being unencumbered with the past ideas which you have tried to use and failed. Because then you think 'Oh, the idea is dead' when it's only the particular approach which you took to the idea which may be dead. I think the younger you are the better it is, if you can take the risk."

"Now were you young when you began to work on your unification theory?"

"The idea started about 1957 when I was thirty-one which is fairly young, but then it took a long time in the execution."

"And did you get up every morning and work on it?"

"No, no, not at all. It was intermittent. You worked on that particular set of ideas, then you gave up and took up something else and then you came back to it and so on, publishing little bits as you went along."

"But were you ever wrong? Have you ever been wrong in a major sort of way?"

"It's probably just egotism but I can't think of anything where one has been proved completely wrong. There have been many stupid ideas which have led nowhere, of course, but that's the fate of all of us. The majority of our ideas, 99 percent, lead nowhere. You're lucky if *one* of your ideas is correct in the end."

"And you have no misgivings about that?"

"Not at all. But I think in our subject when you look at the successful ideas, you feel there is an inevitability about them. The only word I can use is 'sleepwalking'. The *sleepwalkers* is the title of Arthur Koestler's book about Copernicus, Kepler, and Galileo. You just are led more or less from one step to the next."

"Sleepwalking seems a very passive way of doing physics."

"It's sleepwalking in the following good sense. The unification ideas needed what we call the gauge theories. The gauge theories were actually first discovered in 1879 by Maxwell – as suggested by the equations for electromagnetism he had written down – then clarified by the German mathematician Hermann Weyl in 1929. They were put into the form in which we use them today by Yang and Mills and my pupil Shaw in 1954. It was the same old set of ideas which had started with Maxwell in 1879 but put in a slightly larger context. Then we, that is Weinberg, Glashow, and myself, said 'These gauge ideas are the ideas that we need.' That was our contribution. Newton, you remember, was asked why he was so great and he said 'I was not so great. I was standing on the shoulders of giants.' So my own feeling is that in each generation there is a set of ideas which is more or less common, but people forget and ascribe the entire success of those ideas to the one man who makes the best use of them. In that sense, maybe, physics has always been sleepwalking. When I said that in 1879 Maxwell had a great idea – well, he had inherited a set of ideas from Faraday. He wrote down Faraday's equations and found they were inconsistent, so he supplied one extra term. So in that sense it's inevitable, it's sleepwalking. Take Einstein's ideas which we consider the most revolutionary, the ideas of the curvature of space and time which explain gravitation. They go back to the German mathematician, Gauss, who first, in fact, made the tests to determine the curvature of space. What he didn't do was to put time into it. So there's an inevitability about these ideas. Although it was an act of genius for Maxwell to have found that extra term, and for Einstein to have added time to three-dimensional space, if you trace the history of the ideas they go back by gradations to earlier and earlier generations."

"Do you think if there hadn't been these geniuses these steps would have been made anyhow?"

"Yes, I do."

"Now, you come from a religious background, was there ever any conflict in doing physics?"

"No, why should there be? Because fortunately, and I think I have said this so often in my writings, Islam is one of the three religions, which emphasize the phenomena of nature, and their study. One eighth of the Qur'an is exhortation to the believers to study nature and to find the signs of God in the phenomena of nature. So Islam has no conflict with science."

"What is the pleasure that you got from physics?"

"Well, let's put it this way. When you go to sleep and you are exhausted after a day's administrative chores or whatever, what is the thought that gives you maximum relief? I don't know what it is for you, but I get my pleasure from thinking about the problems of physics. It gives me the biggest relaxation."

"You mean thinking about physics is not work for you?"

"It's a pleasure. I should qualify this by saying that when you are working something through it can be very, very hard and you eat your heart out. You think this idea should work and it doesn't. Then it can be devastatingly worrisome. But otherwise, most of the time you're thinking about it, it's a pleasure."

"What is that pleasure? Is it the pleasure of reflecting on what you've done that day, or contemplating the beauty of physics?"

"Well, after you have found something it's marvelous."

"So, it's success which gives you pleasure?"

"It's not just success. When you are relaxing, as I described, you are not reflecting on the successes of the past. In fact, any paper which you write does not give pleasure for more than a few days. I think for a week at the most. For a week you may be euphoric. 'Oh yes, that was a marvelous result.' But then it becomes just part of you. Presumably it becomes a part of your pleasure-giving cells, wherever they are, and impels you to further work."

"Do you still feel a sense of awe at the extraordinary nature of particle physics?"

"Yes. It is always incredible that what people work out actually does happen."

"But are you more impressed by what people work out, or by what the nature of Nature is?"

"Both. As a phenomenon, take Brain Science, for example. It is marvelous. So in that sense physics is not unique. But when I think in terms of the sublime theories that come in physics, I think that is unique."

"Do you like music? I mean, do you get the same sense listening to music?"

"I would not say that I find the same sublimity. I find the same sublimity in reading or listening to the Qu'ran, because there I find, for example, after you've been listening to it for half an hour, you suddenly get caught in an elevating fashion."

"But you do see physics as sublime?"

"Yes, yes, no question about it. I mean take Einstein's theory – you still, after so many years, you still think: What a sublime, what a marvelous idea it is!"

Daily of Chir Science Center

Dr. Rafeel S. Baaklini, Director of Chir, Lebanon

To Abdus Salam

سَلَامُ اللّٰهِ يَا عَبْدَ السَّلَامِ ۞ عَالِمُ أَصْرَافِكَ طُورُ الدَّوَامِ ۞
عَلِمَ كَرَامَتِكَ نَبِيَّ الْعِلْمِ أَنْهَمْتَ ۞ مِنْهَا لَقَدْ نَزَّاهُ فِي الْعُلُومِ ۞
مَنْ حَضَرَ الشَّرْقَ مِثْنًا حُلْدِيَا ۞ فِي دَرْبِ الْبَحْثِ وَالْإِسْلَامِ ۞
نَادَاكَ دَارُ السَّيْرِ عِلْمًا ۞ بِطَرِيقَةِ الْإِسْتِثْنَاءِ وَالْإِسْلَامِ ۞
وَأَرَادَكَ دَارَ الْمَارِ تَامَ بَعْدَهُ ۞ لَمْ يَزَلْ الْعِلْمُ بِالْإِسْلَامِ ۞
مَا لَنْ سِرَّ لَارِ أَمَامِ مَكَّةَ ۞ لِنَاسِكَ الْإِسْلَامِ وَالْإِسْلَامِ ۞
عَلَى أَرَادَ اللّٰهُ نَكَرَكَ جَمْرًا ۞ نَزَّاهُ دَرْبَ الْإِسْلَامِ وَالْإِسْلَامِ ۞
وَقَطَرُ يَابَعِ السَّلَامِ سَارًا ۞ الْإِسْلَامُ يَا عِلْمَ وَالْإِسْلَامِ ۞
نَظِيرُ سَجْدَةِ الْعِلْمِ ۞

1 ad 1974

اسے نگار علم و دانش اسے عمیق اسے سلام
اسے حکم را از جوهر اسے سرمد رنگ و بزم
اسے فکر اسے مقصد قوس کے انقباض
تو کشوری عقده ہائے راز کی پید و فطام
تو سنا زوالت شبیں در کاروان مسلم و من
تو شراب کرب صواب و رفعت اسے صبح و شام
وصلی وقت طبعیں کردی جو جس کسر و در
ی فسان و ریشیاں اصل اصول نظم و عام
تو مجریض فوکی تو بہت را اندر بہت را
تو مثالی شعر و فلسفہ خود چپا ام اندر چپا ام
چون نوائے فیض گستری رسی با کار جویش
ی مکی امیں راز و فلسفہ آشت کارا بر عوام
حق طبعیات را از میناسکی بر دوش عقل
تو نگار و صلح را مضافہ نقش در دام
تو سرا پا خلق و انفت تو نوائے کیف و دل
تو سحر و دانش با تہمت موج رشام
تو ستم و لر با را کیف ہائے سوز و ساز
تو ہائے شعر و فلسفہ تہمت روج رحمت

63. Arabic and Urdu Poems in Praise of Abdus Salam

- a. Arabic Poem by Nazir Baaklini, Lebanon b. Urdu poem by Asim

56

Grand Unification: A Tribute to Abdus Salam

Fred Reines

From out of the East there came a man
Who thought to divine the cosmic plan
To unify the hearts of man
And make whole, concepts deep and grand.

From out of the West came Nobility
To grace the deep insight, the unity
Arising from diversity.

From out of the East there came such a man
Whose heart and mind did most nobly span
Man's highest hopes and dreams and plans
Transcendent with love and humility.

From out of the depths of the human soul
Came this man so well crafted for this role
Came this man who would make
That which is fragmented whole.■

International Centre for Theoretical Physics,
Trieste, Italy
November 3, 1989



64. Fredrick Reines, 1995
Nobel Physics Laureate

57

Physics for the Poor

The Economist, London
November 18, 1989

In 1949, a 23-year-old Pakistani called Abdus Salam earned a first-class degree in physics from Cambridge University in only one year, an almost unheard of achievement. In 1950, he solved a problem in mathematical physics that had been holding up theorists, and became famous (at least among particle physicists) overnight. Then in 1951 he returned to his native Pakistan, and found himself isolated. Without a library and bereft of colleagues, the only theoretical physicist in the country spent three years doing little more rewarding than managing the college football team. In 1954, he returned to Britain, a reluctant brain-drainee.

Since then Abdus Salam's theories about the symmetries of nature have earned him a Nobel prize. But he has not only changed the way that physicists think; he has made a new place for them to think in. In early 1960s he urged the International Atomic Energy Agency (IAEA) to provide physicists in poor countries with an alternative to emigration. His idea was a place where they could catch up with their craft as practiced in Western Europe and America, and then go home refreshed and up-to-date. In 1964, the agency agreed and the International Centre for Theoretical Physics (ICTP) came into being. The Italian government provided more money and a building in Trieste. The Centre is now one of a number of similar institutes there, and part of a fast-growing network of scientific expertise.

To celebrate its quarter century, and to honor the man who made it possible, the Centre hosted a conference at the beginning of November, a tour d'horizon of the physical world. Leading physicists gave talks on the latest marvels of their fields, from pools of fluid electrons sandwiched between semiconductors, to the huge, all-but-invisible rafts of 'cold dark matter', which may or may not make up 90% of the universe. Dr. Ludvig Faddeev, of the Stetlov Mathematical Institute in Leningrad, intrigued a skeptical audience with his ideas that the advances of the past century of physics, one of the greatest intellectual stories history has to offer, could be summed up as just the deformation of a generalized set of equations and that the whole thing (physics, not the universe) was about to end.

The diversity and quality of the talks was typical. From the start, it was vital to the success of Dr. Salam's idea that visitors from poor countries should not

From *The Economist* (London), November 18, 1989, pp. 99-100.

merely be offered crumbs from the table – they should dine on ideas cooked up by the best minds. So he persuaded the best physicists of the day to participate right from the beginning. After only four years the ICTP was sufficiently well established to attract a dozen Nobel laureates for a month-long conference.

The Centre has now held some 400 courses, workshops, seminar series, conferences and the like. It has also provided physicists with the time and stimulation to produce over 5,000 papers published in international journals. Since UNESCO joined the IAEA in running the Centre, its activities have expanded beyond theoretical physics into applied physics – that of the earth and the oceans, of molecules and of lasers. It now has laboratories for work on microprocessors and superconductivity – a field Dr. Salam still does some work in, and to which he was introduced, ironically, during his time kicking his heels back in Pakistan.

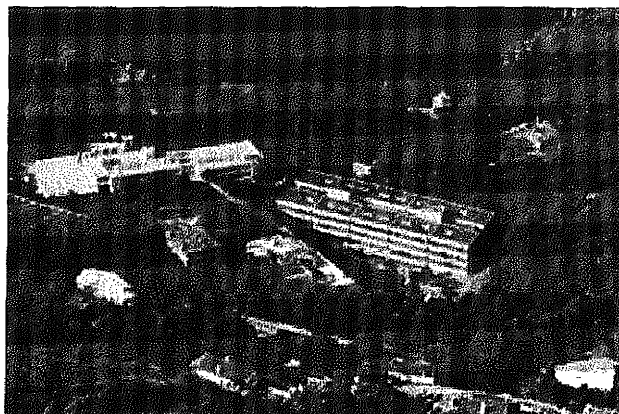
Over twenty-five years, 22,000 physicists from poor countries, often on ICTP fellowships, have passed through Trieste and – for the most part – gone on their way inspired afresh. It is said that every physicist in India has either been there, is going there, or wants to go there. There have also been many visitors from communist countries. During the 1960s and 1970s the Centre was one of the few places in which American and West European physicists could talk to their Russian counterparts. This was one of the Centre's aims from the beginning. At one of the first seminars Dr. Roald Sagdeev, who is now one of Mikhail Gorbachev's closest scientific advisers, almost strangled himself with a microphone cable while over-energetically covering a blackboard with equations about plasma physics, a specialty in which Russian physics was exceptionally strong. Now there is talk of setting up a similar center in Moscow.

Indeed, there is talk of setting up similar centers all over the place, from the Orkneys to Texas. Three more are being started in Trieste, under the auspices of the UN Industrial Development Organization and paid for mostly by the Italian government (which now provides 90% of the ICTP's \$19 million budget). Italy is happy to pay for such things as part of its aid budget, especially since it helps to win Trieste fans as a "science city". One of the new centers will be devoted to chemistry, one to the earth and the environment, and one to high technology and new materials. There is already a Centre for Genetic Engineering and Biotechnology where work is done on the papilloma virus, which has been linked with cancer of the cervix and uterus, and on designing bugs to eat the lignin in dead plants. Trieste also boasts the Third World Academy of Sciences, another of Dr. Salam's inventions, which links institutes and initiatives around the world.

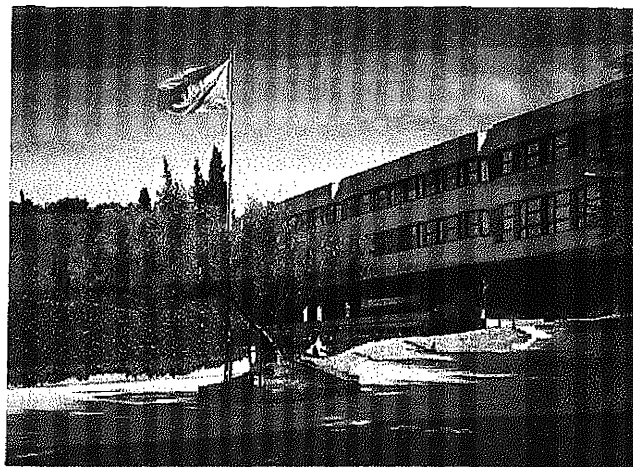
His plans are now reaching new levels of ambition with a proposal for twenty high-technology colleges dotted around poor countries, perhaps with some money from the World Bank. Unsurprisingly, he does not get much time to do physics in the conventional way. Yet there is more to physics than writing equations. By using his charm, determination and intellectual standing to win over politicians he has achieved plenty for physics and physicists in poor countries and elsewhere. Besides, he points out with a grin, the scientific ideas

that he and others put forward two decades ago are still holding up well under experiment – though they have evolved a bit – so he does not feel under too much pressure to cook up new theories just yet.

The fact that the movement that began with the ICTP is broadening and turning to more practical fields of thought does not mean Dr. Salam has retreated from his goal of providing developing countries with better theoretical physics. He has two reasons for championing what might seem an overly sophisticated development tool. One is that high technology depends on the knowledge, training and culture provided by academic physics; poor countries will never be able to compete until they can provide them. The other is that he loves physics and devotes himself to serving it any way he can.■



65. Aerial View of ICTP Campus, Trieste



66. Main Building of ICTP

58

A Unifying Force for Third World Science

Nina Hall

New Scientist, London

Abdus Salam has never forgotten that he had to leave his native Pakistan in order to pursue his life's work in theoretical physics. He firmly believes that talented scientists from developing nations should be encouraged to carry out their research in their home countries. For Salam, a strong base in fundamental science and high technology is the key to national advancement. [...]

Last year, the ICTP celebrated its 25th anniversary with an international meeting where one hundred and fifty physicists, including several Nobel prizewinners, were invited to discuss the latest physical theories in fields from astronomy to condensed matter.

The ICTP, perched on the edge of the Adriatic, close to the Yugoslav border, provides an ideal intellectual, cultural and geographical focal point, where North meets South, and East meets West. For more than two decades, Salam has persuaded the world's greatest intellects to come to Trieste to teach and guide young physicists and mathematicians from the developing South. But more important is that the ICTP functions as a sort of lonely scientists' club for Brazilians, Nigerians, Sri Lankans, or whoever feels the isolation resulting from lack of resources in their own country. [...]

Why has the Italian government been so supportive [\$300,000 plus an attractive building in Trieste for the ICTP to be inaugurated in 1964]? One reason is that Italians admire scientists and, secondly, physicists – the Godfathers of Italian science – are a powerful force to be reckoned with when it comes to apportioning funds. Paolo Budinich, Professor of theoretical physics at the University of Trieste, who was deputy director of the ICTP until he retired in 1978, has played an important role in the expansion of the center. Antonino Zichichi, who was a director at CERN, is another keen supporter.

Even Salam has learnt to speak the kind of language that Italians understand. "In 1979, after I won the Nobel prize, I told the Italian government I was going to leave unless they increased their contribution to four or five times as much. \$3.5 million was what I wanted. They offered us \$3.5 million."

Equally telling is the fact that the Italian Prime Minister, Giulio Andreotti,

Excerpts from the article in *New Scientist*, Vol. 125, No. 1701, January 27, 1990, pp. 31-32.

when he was Minister for Foreign Affairs, saw funding research in science and technology as an important part of overseas aid. Italian civil servants were quick to point out that what is good for the Third World could also be good for Italy; initiatives channeled through the ICTP would also stimulate locally produced science and technology.

Building on the success of the ICTP, Salam is now anxious to carry through his vision of high technology for all, and has suggested creating a new center for the Third World with three components. One will be a center for chemistry to research into industrially important areas, such as catalysis, polymers and drugs; the second center will be for high technology and new materials, including superconductors; the third and perhaps most interesting center will be devoted to earth and environmental sciences, particularly earthquake prediction and climate.

The UN Industrial Development Organization and the Third World Academy of Sciences – yet another scientific body established four years ago by Salam – are preparing a feasibility report. The Italian government has given \$2.5 million with the possibility of another \$10 million over the next two years.

So far, there has been little financial support from outside Italy. The IAEA currently provides \$1.2 million a year for Salam's center, and plans to keep funding at the same level. The agency has been set a target of zero growth, so is, according to a spokesman, "unlikely to make an exception for new projects". UNESCO now contributes \$400,000 a year, which, says Siegbert Raither, UNESCO's program specialist for physics, "is a huge amount for us". Raither says he is not clear how useful a materials science center, for example, would be but points out that the Director General of UNESCO, Federico Mayor, is "quite enthusiastic" about Salam's proposals. "Salam wants a million dollars a year, which would be a hefty sum for us but not impossible," says Raither.

Nevertheless, financial dependence on one nation naturally worries Salam. The Italian connection has meant that the future of his activities in Trieste is inextricably entwined in the knotty tangle of Italian politics and the rigid bureaucratic infrastructure of Italian science. Salam quotes a recent example of connivance, Italian style, when the Italian government gave the ICTP extra money to pass on to the University of Rome, so that Rome could be seen to be obtaining "foreign" support.

Salam is also worried that the ICTP and its offspring will become too European. He does not share the enthusiasm of some scientists at Trieste for building up links with Eastern European countries, which may or may not be classed as developing nations, depending on your point of view. Salam wants to see the ICTP as the nucleus of a more international network firmly based in the Third World.

Organizations such as UNESCO could not provide the millions of dollars needed for such an ambitious project. And, as the organization's spokesman hinted, such a network could compete with UNESCO's own network of scientific centers. For this reason, Salam has been to see Robert McNamara, former president of the World Bank, to try to obtain support for twenty new centers to be

established in developing countries around the world. Although McNamara is enthusiastic, \$50 million a year is the most Salam says he could expect to receive.

Salam realizes that such a scheme has little chance of becoming a reality unless there is a firm commitment on behalf of political leaders of developing countries: "The project needs a lot of money." He suggests that each country should put aside one per cent of its GNP for science and technology. Some countries, such as Jamaica and Venezuela, are enthusiastic, but Salam recognizes that convincing many others with perhaps pressing political problems will be a long hard struggle. "But I go through life like a sleepwalker. I never worry whether something is going to be a success or not."¹¹



67. With Zhou Enlai in Beijing, 1972

59

The Cambridge Days

Nicholas Kemmer
Former Professor of Physics,
Imperial College, London

I am most grateful, and flattered, to have been asked to recollect the wonderful years (1946-1953) in Cambridge into which Abdus Salam entered. They were indeed wonderful years for me but not solely for the reasons connected with this memoir.

During those years I met and married the dear woman who has shared and enriched my life ever since. Also, although Abdus Salam's entry into my story proved to be the start of a most important chapter, it is not its beginning. There is a lot that I feel I must tell first, so I beg readers to have patience, awaiting the central character to enter the story.



68. N. Kemmer

I first got to know Cambridge during World War II, when it was much depleted, with a lot of its atmosphere lost. I was then not officially attached to the University but one important attraction for me had not vanished. A man was still there who had been one of my heroes ever

since I first heard of Quantum Theory and the physics of the atom. He was then occupying the Chair that had once been Isaac Newton's – Paul Dirac. He had given *Quantum Mechanics* its definitive form, then created *Relativistic Quantum Mechanics*, and gone on to start constructing what we now call *QED*, Quantum Electrodynamics – the description of how electrons and photons interact. Sadly, Dirac never did succeed in making QED a complete theory. To the end of his life he remained unhappy with all later advances in QED that were to be made by others and thought even less of the work of many others (of whom I had been one in a small way) who were attempting to use ideas, related to QED, for describing the various new particles that experimenters kept discovering.

The happenings that got me to Cambridge during the war allowed me to meet Dirac within his family, as a charming, modest and rather withdrawn man, capable of uttering words of penetrating depth, but very, very few of them. After the war, when many of the dons returned and Cambridge quickly regained its former splendour, there was a flood of exceptionally bright students, some youngsters but also many war veterans. Dirac inspired many by his renowned lectures, but firmly resisted taking on the many students hoping to do

postgraduate work under him. There were no other potential supervisors for these students left in Cambridge in 1946 and to my surprise and honor I was appointed Lecturer in Mathematics and then elected Fellow of Trinity College to fill the gap. Immediately, I discovered that my teaching load was heavy. True, half my lecturing duties were a course to follow on Dirac's, quaintly called 'Nuclear Physics'. This I was able to make enjoyable for myself. These were familiar topics including matter that I knew well from my own training and research. The other course demanded knowledge only partly on topics in Applied Mathematics of which I had not learnt anything as a student. What is more, Trinity College expected me to conduct tutorials on all these topics – a form of instruction that had been non-existent in my own student programme on the Continent! This, however, did not end the duties that I found myself accepting from the very start. Postgraduate students were queuing up to take me as supervisor instead of Dirac. Finding research topics for them always is a difficult task for me – and at that moment it couldn't have been more difficult. That was because the questions that had developed in the field that I had been most competent in when war broke out were getting more and more baffling and confusing.

Let me relate a well remembered conversation that took place one day as I emerged from a lecture I had just given, with two of my audience whom I'll call A and B:

A: "Theoretical Physics seems to be in such a mess, that I have decided to switch to Pure Mathematics."

B: "That's curious, I have decided to switch to Theoretical Physics for precisely the same reason!"

A's name need not be concealed – he was the late Harishchandra who moved to the USA and became a highly respected Algebraist. I had taken him over as a Research Student at the very beginning from another supervisor who had left Cambridge. However, my story tells better if I conceal B's identity for a little while.

Fortunately the very bad state of my subject, Quantum Field Theory, did not last very long. The then new means of communication that colleagues had just begun to use – exchange of preprints of papers – soon brought exciting news from the USA, which I of course conveyed instantly to my research students. It started with experimental results. New high precision measurement techniques out of wartime research had produced exciting facts to underpin QED. This prompted theoreticians to start a reformulation of the ideas of QED – a start of the approach soon to be called Renormalization. Results of amazing accuracy began to emerge. After barely a year we received from the USA not one but two seemingly different theories of Renormalization, one expounded in great detail by Schwinger in the reports of a conference – and of course studied by us as well as the rest of the scientific world. (It was soon discovered that Tomonaga in Japan was offering essentially the same idea!) The other was by Feynman, and reached us in a very condensed and puzzling form that left people puzzled.

All this happened not long after I had advised the man B of my anecdote, not one of my students, but a recent Ph.D. off on a scholarship in the USA, to go to Cornell there. There he found himself in the thick of the development of Renormalization and quickly was able to offer the world a version of Feynman's theory to be understood and admired as beautiful and most powerful. In the same breath B also proved that Schwinger and Feynman were offering the same ideas of Renormalization, albeit stated very differently. (B also has related that he owed a lot to me for giving him the tools that sent him off on his new career so promptly.) B is Freeman Dyson.

Among my students one in particular turned the study of the new ideas of Renormalization in a particular direction that was close to my heart – to the question of whether what could so spectacularly transform QED could also be applied to the other field theories needed to describe the interactions of other particles. A priori the chances of success there were not great because QED dealt with a very weak interaction, the other theories decidedly did not. Paul Matthews tackled this question and though not unexpectedly, his success was limited, it was enough for him to build a Ph.D. thesis around it and to gain him a scholarship to Princeton, once he passed his examination.

Around that time I was presented with a difficult personal problem. Some of my colleagues, both theoretical and experimental, approached me demanding, "You must accept one more research student." "Impossible! Not many have been as easy to cope with as Paul Matthews. He'll get his Ph.D. and will be off my hands!" "But this one has done better on his finals, both in Physics and Mathematics, than anyone we sent you before!" "Who is he, anyway?" "A Pakistani".

What I answered will remain a conjecture, but is bound to have expressed great doubt, about the man's qualifications being good enough. Anyhow, no doubt blaming myself for weakness in taking on more hard work, I accepted, but got myself out of immediate responsibility for devising a research problem for the new man by telling him that Matthews was the man who had made himself expert in the problems he should study and sent him to consult Matthews. It was not at all long before – my memory is bad of the exact time sequence of things at that point – when I found Abdus Salam – of course that was who it was – studying the great papers by Dyson, puzzling about some residual points that Dyson had not made complete and sorting them out. Then Matthews came to me to say farewell and saying: "I had worked out a program of study for Princeton, but this chap Salam has solved my intended problem!" So as early as that, Abdus Salam already made a mark among those contributing to the subtleties of the theory of Renormalization – and I had another unexpected problem.

Matthews had started Abdus Salam off to work which he was much more competent in than I. Princeton, not Cambridge, was where Abdus Salam should be, but he was enrolled for a Cambridge Ph.D. The regulation would not allow him to go somewhere else unless there was a qualified Cambridge man on the spot to supervise the student. Rather with tongue in cheek, I pointed out that there

was such a man there – Dr. Paul Matthews! This was the somewhat bizarre beginning of what soon became a long-lasting and close friendship between two wonderful people.

There was just one serious obstacle to this promising collaboration that could have turned into a big loss to Western Theoretical Physics. The readers of this memoir will know only too well that Abdus Salam, even when caught up in becoming known and accepted as a serious contributor to Theoretical Physics in the West, never forgot the debt he owed to his home country and the people who enabled him to become what he was. So, many opportunities he saw as not for him. Every year he went home, cut himself off from us in the West, not just because he was so conscious of his obligations, but also because he believed, rightly, that he could do much for the progress of his country. That this indeed proved to be right, we all know – and beyond it the whole world has become indebted to his activities in wider spheres. However, during the time I remember he was happily able to be back in Physics at first principally in collaboration with Matthews, and the stream of contributions to Elementary Particle Theory continued to grow right up to the highest possible culmination.

These are things all the world knows, but over all the time since those wonderful Cambridge days, though my contact with Abdus Salam became infrequent, there still were many personal memories. There were the early efforts to get the Trieste idea off the ground and then the triumphs of its completion. There was our private pleasure in Edinburgh to be the very first University to award him an Honorary Degree, long before the Nobel Prize. Then, skipping many other happy moments, my surprise last year when, entirely unknown to me, the City of Edinburgh, my home for the last thirty-seven years, decided to create an annual Science Festival with the conferment of an Edinburgh Medal and chose Abdus Salam as its first recipient, with plans for active collaboration in future designs of aid for science in the developing world.

Abdus Salam is never very far from my thoughts. Though I cannot be present, I am delighted by letting these lines contribute to the good wishes for his 65th birthday.¹ ■

Edinburgh
July 11, 1990

¹ The article is signed as follows:

“Nicholas Kemmer (who was first in guiding you [Abdus Salam] into Theoretical Physics)”.

60

Excerpts from Selected Tributes to Dr. Abdus Salam on his 65th Birthday, Trieste, January 29, 1991

60.1 Prof. P. Budinich, Former Deputy Director of ICTP.

Today we are celebrating the 65th birthday of our friend and Trieste Citizen Abdus Salam. It is a pleasure for me to briefly remind the story, which brought gusto to this event. The coming of the ICTP in Trieste and the consequent beginning of my friendship with Abdus Salam was the result of the combination of a series of improbable circumstances like the fact that in 1961 he was in Geneva and then in the range of distance from Trieste (like Bologna, Vienna, Zagreb) from where we could afford to invite people to our summer symposia. The fact that in the same year he convinced the Pakistani delegation at the IAEA General Conference to propose the creation of an International Centre for Physics under the flag of the United Nations, the fact that Edoardo Amaldi brought immediately the news in Rome where I was by chance, the fact that Salam immediately answered from London to my letter proposing the Trieste candidature, the fact that Minister Fanfani immediately committed the Italian Government in favor of Trieste, in such a way that when, a couple of months later, La Pira proposed the candidature of Florence it was already too late.

Should one of these coincidences have been missed, the ICTP would not be in Trieste but perhaps in Copenhagen or in Vienna or in Florence and my acquaintance with Salam would have remained a scientific one. Instead it has developed in thirty years as a friendship "for life" as he wrote presenting me a copy of his book. This is what some people call destiny. It was a good sound friendship, not an easy one, with some occasional tempests as in good sound marriages.

Good friendships, especially between people coming from different parts of the world, from different environments, are always fruitful, they may only improve people. On my part I understood Muslims and their deep cultural values, maybe I adopted some Muslim habits, and I am convinced that Salam appreciated our values. Someone told me some days ago to be surprised by his human (I think he meant Christian) gestures.

But the deep link between us originated mainly from the enterprise we started here in Trieste, which during its rapid expansion, more and more convinced us of its usefulness and of its necessity for the benefit of the World in the South but also with our neighboring friends in the East with whom we have kept and developed during twenty-six years valuable links of scientific, cultural and personal collaborations.

Here in Trieste we have experienced how the values of science and culture can only unite people, help them to understand each other, to cooperate and to live and progress in peace.

It was a privilege to have had the opportunity to be able to offer to the thousands of young people coming here, the values of science and culture they asked and needed; after all this opportunity is one of the best satisfactions a man may ask for from life.

In the past this of the ICTP was a useful activity. But especially now the aims and ideals which oriented the ICTP enterprise might become of great value also as a remedy to the disaster, damages and bad feelings which the present war will certainly leave behind. In the future the continuation of the ICTP and its expansion to ICS and ICGB to cope with the ever increasing needs and demands from the South and from the East will be an absolute necessity.

60.2 Dr. Hans Blix, Director General, International Atomic Energy Agency, January 29, 1991.

Dear Abdus: Important commitments prevent me from being with you in Trieste, today, on the occasion of your 65th birthday but I wish to add my congratulations to those of so many distinguished guests honoring your accomplishments and paying well deserved tribute to your untiring efforts to promote the development of science in the Third World.

Thanks to you and your staff, the acronym ICTP and the city of Trieste have become familiar to all physicists; and more than forty thousand of them in the past twenty-seven years have been associated, in one way or another, with ICTP's activities.

Under your guidance the Centre has known a tremendous development and success and while the generous, ever increasing, support of Italy to the activities in Trieste must be gratefully acknowledged, there is no doubt that at the base of this support are the ideas and ideals underpinning your work.

The Agency takes pride in its long association with ICTP activities and intends to continue its financial and other support to the program irrespective of any future changes that the expansion and diversification of ICTP activities might make desirable. Yours sincerely, Hans Blix

60.3 Prof. L. Bertocchi, Deputy Director, ICTP.

I would like to share with you some of my experiences with Abdus Salam, both as a scientist and as a science administrator.

I am one of the many physicists who took part in Italy in the anti-brain-drain phenomenon, moving from a big university, Bologna, to a university which was, twenty-five years ago, a small one, and I came here, to the Department of Theoretical Physics, attracted by the existence of the International Centre for Theoretical Physics.

My first real scientific interaction with Salam took place when I had just arrived in Trieste, coming from CERN. In those years, 1967-68, one of the key items in physics was the theory of the Regge Poles and of all the phenomenology related to the Regge Poles. Since I had some experience in this area, I was asked to deliver a course at the postgraduate school of the Trieste University, whose lectures were held here at the Centre.

To my astonishment, when I started my lectures, I found, sitting among the students, Professor Salam; and I must say that he was by far the best and the worst of those students: always asking questions, never allowing me to talk for more than ten minutes without interrupting, discussing details, wanting to master all details. He went so far to force me to change the timetable of the course, in order to be able to attend all the lectures! This is an aspect of the personality of Salam: always curious, always eager to learn and reinterpret theories and facts in his own way.

I said that this was my first real scientific interaction with Salam; but I always like to remember when and how I first heard his name. At the beginning of 1956 I was a young student, preparing the Italian *tesi di laurea*, which was about one of the most advanced topics at that time: dispersion relations.

The real difficulty for me was that the key papers, to be studied before starting the real work, were all in German; and my German was and is quite poor, so I had a lot of pain in reading those articles.

One day my supervisor came to me and said: look, I have just received some lectures notes on dispersion relations; they have been written by an oriental, I think an Arab or an Indian, working in England, a certain Salam. These notes were for me fundamental for their clarity (although the handwriting was as bad as it is now), and I was able to judge already from them one of the main features of Salam as a scientist: the capacity of singling out the key points in an argument.

Let me now switch to my experience with Salam as a science administrator (although probably this is not the best term: it would be much better to use the term of creator of scientific institutions, or promoter of science, especially in the Third World).

I have been fortunate to start my cooperation with the Centre twenty-four years ago, when I moved to Trieste, and I have been "captured" more and more by Salam, starting first with the organization of seminars, then of course, to end with the responsibility of the Centre as Deputy Director. These last ten/fifteen years have been those of the tumultuous expansion of the Centre in a very rapid way, mainly thanks to the generous financial support of the Italian Government, and, whatever parameter you consider – number of scientific visitors, number of scientific activities, space available, budget – everything has increased by a factor from 8 to 10. You can imagine that this required a lot of work and re-organization, scientific, administrative and logistic.

However, for Salam this is never enough. We had not yet consolidated the large expansion of the Centre to essentially all the fields of physics, technology,

environment and mathematics, with new programs in Trieste, in Italy and outside Italy, and Salam created the Third World Academy of Sciences; the Academy was not yet consolidated, and Salam launched the three new Centres of ICS: Technology and New Materials, Environment, and Chemistry. The International Centre for Science is now still in the project phase, and Salam has just started a new program, the Diploma Course.

As a result of his vision and effort, he has been able to realize all the scientific complex which exists now in the so-called Miramare Area. And tomorrow he will surely come with some new creative idea. I can assure that with him there is never a dull moment (*in italiano: con lui non ci si annoia mai*). From this point of view, he shares this quality with the other great man who with him has created the Centre, Paolo Budinich, who also never stops creating new institutions.

Another distinctive feature of Salam is that not only you never do enough, but it is never too early to do something; his motto could be: never do today what you could have done yesterday; moreover, the work which is done by three people could always be done by two or perhaps even by one; all funds have to go to science, and only the bare minimum to administration.

I will end my talk underlining, among his qualities, the one which has always impressed me mostly: the capacity of switching immediately and fully from one subject to another – he could discuss a deep problem in physics with the scientists of his group, then, if interrupted, switch to an administrative problem and discuss this new matter with full attention, to return fully to physics in the time of a few seconds. I know very few people who have this quality at such a level.

I think that I will close these remarks with one sentence: Abdus, working with you is hard and difficult, but always exciting. Happy birthday.

60.4 Professor G. Salvini, President, Accademia dei Lincei, Rome, Italy.

The man we are honoring today is the key person of a part of history of physics of this century. Together with two others he opened the way to the understanding of the electromagnetic and electroweak interactions. This was a fantastic thing. It took many years.

The idea of trying to have evidence of these particles through experiments of the particles divined by Abdus Salam and the others was very, very touching and looked very impossible indeed.

At the end, the research developed and it was decided that it was possible to find these heavy particles. They were found in 1981-82-83. The main author of this gigantic experience was Carlo Rubbia and I can tell you that as soon as they were discovered there was a flux of people coming here to Trieste to Abdus Salam. We remember Carlo Rubbia coming, Zichichi coming ... I was very busy at that moment just on these particles. It was a recognition that these key points of the history of the world in all the world had started from Abdus Salam. It was

a long chain of scientists. No man can do this alone. There were hundreds of experimentalists and theoreticians, but certainly Abdus Salam deserves a highly significant part of these discoveries.

This is the part for which I am particularly related to you independently of other aspects of this beautiful celebration.

I cannot comment but with admiration on what has been said by Budinich, by Bertocchi and by others for your activity. Certainly it was a miracle and destiny. Miracle, coincidence, you can call it as it is, but certainly this friend coming from out of Europe just brought to Europe a hope and a perspective which was new and moving.

I could experience this from Rome. I was for a period in the National Institute for Nuclear Physics as President and I remember very well the attitude of Amaldi, which has been recorded by Budinich and which was as generous. They are two generous men, Abdus Salam and Amaldi, they are really something from the point of view of creating activity. And also when Antonio Zichichi was President of INFN, he was also very sensitive to these activities. We had the occasion to discuss. He is not here, but let me tell you in his place that he would be very happy to be here to tell you how much his activity was intense. This is something and the hard days of today make us meditate on what happened and what will happen. [...]

Let me just conclude with one point of science, Professor Salam. You opened the way to electroweak interactions, to the standard model, but this way you opened remains with a black box closed. If you open the box you find certainly something, maybe the Higgs, maybe not, but certainly in this black box there is something not well identified, there are these color fields. If I can then indicate to your responsibility the next step, let me say that the Higgs is waiting for you and I invite you to open it.

60.5 Prof. M.H.A. Hassan, Executive Secretary, Third World Academy of Sciences, Trieste, Italy.

I first met Professor Salam in 1974, I do not know whether he recalls that, but it is a fascinating story and I would like to tell you. It was nearly six months after I returned from Oxford to start teaching at the University of Khartoum, and during these six months I went through a very agonizing experience as far as research is concerned. I was graduated in plasma physics, there was not a single journal in plasma physics, not a single book. All I had was my thesis and a few research papers that I managed to get before I left Oxford.

My father saw this frustrating experience of mine and decided to induce me to work with him in a project which he launched, building a soap factory in Sudan. I was fascinated by the project but I was more fascinated by the fact that he asked me to go to Italy to buy the machinery from a company in Milan. I was very interested because that gave me the opportunity at least to come and say hello to the ICTP, to Professor Salam, and to see what he can do to help me.

So, after I successfully purchased the machinery from the Milan company, with an amount of about half a million dollars, a very large amount of money, I ended up here at the ICTP, without telling anybody that I was coming. It was about 6 o'clock in the evening and I allowed myself three or four days to get into the bureaucracy of seeing the secretary and making an appointment with Professor Salam. You see, in our University of Khartoum, if you wanted to see the Vice-Chancellor you would have to wait for a week. At 6 o'clock the Centre was completely empty, except a door that was wide open, and there was Professor Salam, sitting, working. So you can see how fortunate I was. So I went to Professor Salam and I explained to him my problems. I said, I am going to work in the University of Khartoum just doing teaching, but I am going to spend half of my time working with my father. So, he said, "I will give you two options you can consider. One, I know that there are two or three high-energy physicists working at the University of Khartoum, so maybe you should think of changing from plasma physics to high-energy physics. The second option is, you may apply to come to the ICTP. At least you can see the Library and work here."

The first option I disregarded completely, because it would have been a very difficult experience for a fresh graduate to start a new field, but I took the second one seriously and he asked me to go and think about it and write to him.

So, immediately I took my decision. I wrote a little letter to him and I handed it to the secretary. The following day, I went to the Library and I was absolutely fascinated by the books and the journals. The accumulation of everything that I really needed to do research was there. What fascinated me also, was the fact that I saw my first research paper in print, in the general plasma physics. So like many of my good Egyptian colleagues, I spent five solid days in front of the photocopying machine, photocopying journals. I spent five days and the per-diem was spent by my father.

Before I left for Khartoum, I was very curious to know what happened to my little note. So on I went, a very collaborative secretary showed me Professor Salam's comment. And it was written, "Young promising scientist", it was addressed to Professor Budinich and in a nice, almost perfect circle he wrote "should be helped". So I went back to Sudan, and a few months later I received a letter from Professor Budinich in which he invited me to come to the Centre the following year for three months. From that time, I got into the habit of always looking first at Professor Salam's sentence when he sent me a note, because it contained the most important information.

So that was my first experience at ICTP and I am sure that it is typical of many of our colleagues here.

Professor Salam could have devoted all of his time to creative intellectual research in which he had already made significant achievements of the highest distinction. Instead, he has been devoting a great deal of his time in pursuing the fulfillment of his other passion: the promotion of Science and Technology in the Developing World. It is this intense passion which made him establish this

Centre in 1964 as my colleagues just mentioned, and which prompted him nearly twenty years later to create the Third World Academy of Sciences.

This idea of mobilizing the scientific leadership in the Third World under an academy of excellence was first mooted by Professor Salam in Rome in October 1981 at a general meeting of the Pontifical Academy of Sciences. After discussing it with Third World Members of the Pontifical Academy attending the meeting, a memorandum was drawn up in support of the initiative and Professor Salam was requested to follow it through. The Academy was subsequently founded in November 1983 by Professor Salam and a group of forty world-class scientists from the Third World, including the living nine Nobel Laureates in Science of Third World origin.

Immediately after successfully founding the Academy, Professor Salam, who was elected first President, started the very difficult task of searching for funds to fulfill the objectives of the Academy. With the exception of the Canadian International Development Agency which provided a small initial grant of Cn \$50,000, no support was received from any of the funding agencies contacted, several of which did not see the real benefits of creating a special organization for fostering the best of Science in the Third World. It was almost one year after its foundation that President Amoretti, on the occasion of his visit to the Centre in 1984, made a monumental announcement on behalf of the Italian Government to support the Academy with a grant of US\$ 1.5 million. This visionary action by President Andreotti, who was then Foreign Minister of Italy, made it possible for the Academy to convene a major inaugural Conference in July 1985 at which the Academy was officially launched by the Secretary General of the United Nations.

Within a span of five years the Academy has acquired through its Membership and Programs internal prestige and reputation of very high level. It has already made a significant contribution to the promotion of Science and Technology in the Third World and has given new hope to Third World scientists. Those who doubted its usefulness before it was launched are now turning to it for collaboration and advice in all issues related to Science and Technology in the Third World.

Nearly one year after the inauguration of the Academy, Professor Salam started yet another intensive campaign aimed at convincing the political leadership in the South to take appropriate decisions to develop Science and Technology by utilizing their own resources. During the period 1987-88, he personally visited a number of Third World countries and met with various Heads of States who promised their support. His strong conviction that the current poor status of Science and Technology in the Third World can only be improved substantially by the countries themselves, prompted him to propose during the TWAS Second General Conference in Beijing in 1987, the establishment of a Network involving Ministries of Science and Technology, National Research Councils and Academies.

The Network was successfully founded in Trieste in October 1988 by a group of over ninety participants, including fifteen Ministers of Science and

Technology and Higher Education, who at the end of the meeting elected Professor Salam as President and issued a joint declaration known as *The Trieste Declaration on Science and Technology as an Instrument of Development in the South*. Currently the Network has one hundred and fifteen Members, including twenty-five Ministries of Science and Technology, forty-one Research Councils and thirty-three Academies from sixty-eight Third World countries. It has established four regional offices. It is Professor Salam's hope that the Network will eventually be an effective force in convincing the governments of the South to at least double their expenditure in Science and Technology and increase the number of scientists and technologists to the level of at least one thousand per million in each country before the turn of this century.

For the last five years, I have had the great honor and privilege of working closely with Professor Salam as Executive Secretary of the Third World Academy of Sciences. Working with Professor Salam is a thrilling and fascinating experience. It could sometimes be difficult as he is constantly innovative and is always a few steps ahead of everybody, and it may sometimes be frustrating while trying to catch up with him, but I assure you that working with him can never be boring. What has made Professor Salam so successful is his determination to act quickly and decisively on new ideas, in as much as that what would normally take a month to fulfill should be completed within a few days. In the process of rushing things, mistakes can be made and forgiven provided that these do not affect the work of individual scientists in the developing countries. It is no wonder that these scientists from the Third World see Professor Salam as a symbol of constant encouragement and hope.

60.6 Ambassador Augustin Papic, Former Member of the South Commission, Yugoslavia.

As an economist, I am not a typical participant in this gathering. And later on, I will explain what it means to cooperate with Professor Salam.

My acquaintance with Professor Salam is rather late. We met at the South Commission more than three years ago. The South Commission was an independent, non-governmental body created to analyze the position, the problems of the South and to suggest recommendations for their solution. It has been a high-level body presided over by the former President of Tanzania Julius Nyerere; several heads of state, former and actual, were members of the Commission. We have a cardinal, many economists, financiers, bankers, statesmen, politicians, women activists, but Professor Salam was a unique, most distinguished member of that Commission. I say this both due to his highest scientific reputation and because it was the first time a Commission like ours (unlike for example the Brandt Commission) invited a scientist to participate.

The statements of Professor Salam at the Commission's meeting were received with high appreciation, and they were intellectually most superior ones.

However, within the process of the work of the commission, there were some differences in opinion and a lot of discussion, particularly as to how to define and integrate Science and Technology into the process of development. Here I discovered a special quality in Professor Salam. Besides intellectual superiority, he has the quality of persistence. Besides discussion in the Commission, in order to make his views clearer, he published *Notes on Science, Technology and Science Education in the Development of the South*. The famous "Red book" was distributed not only to the members of the South Commission but to a very broad audience outside its membership, to scientists, and for many international conferences. It was everywhere well received (having several revised and improved editions). With the continued efforts of Professor Salam, or Abdus as he was called, with the intensive exchange of views and better understanding with Commissioners, his ideas were adopted and incorporated in the Report of the Commission as the role and contribution of Science and Technology in the development process, within mutual interconnection. The Commission Report was published and launched at the beginning of August 1990 in Caracas, and it is well-known and well-received, distributed broadly within the ICTP family, TWAS and TWNSO Members too. It is now in the process of follow-up and implementation.

Now, for me as an economist, these contacts with Professor Salam have been intellectually most stimulating ones. Why do I say this? Because in these contacts I came to the conclusion that many economic problems I, as an economist, have been dealing with are not possibly solved without adequate recognition of the role of Science and Technology in overall development. This was already shown in the case of the most successful countries in the world, including a few in the South. They were successful because they employed, they gave a proper role to Science and Technology. On the other side all the efforts towards economic adjustment, restructuring in developing countries, as imposed by the International Monetary Fund, failed for the simple reason that Science and Technology was ignored. May I say here that the reforms in Eastern European countries are bound to fail since the huge potentialities in Science and Technology of those countries, although sometimes misdirected, were not employed, were not used.

Now, work and experience in the South Commission represent, in my view, a new page in the life of Professor Abdus Salam. Coming closer to economists, who he still criticizes, he has found it useful to intensify dialogues, to bring together economists and scientists and technologists. Just yesterday, there was a meeting, the second one, organized by Professor Salam with the very distinguished economist Professor L. Emmerij, who is to the left of you, Mr. Chairman, and who is Director of OECD Development Centre, and a few of us, in order to discuss the program, participants and scenario for the round table of scientists and economists.

Coming to the end, being from time to time closer to Professor Salam, what is the phenomenon of this man? I came to the conclusion that he is the

combination of a genius, working very, very hard – I never saw a man working as hard as he does – and being very efficient. Combining all that with the great entrepreneurship – a very rare quality in a scientist – in organizing, chairing and leading very successfully all these institutions in Trieste, with intensive international activities. Abdus Salam is a noble man, fully devoted to Science and Technology for the benefit of mankind, for the benefit of the South in particular in order to secure a better life for “Les Misérables” – the “mustazeffin” (The deprived ones), as he likes to call them.

Professor Salam, wishing you all the best on your birthday, may I express my full conviction that you will continue in the coming years not only to do as much as you did but to open new scientific horizons, entrepreneurial undertakings, so that you never repeat yourself.

60.7 Prof. A. Tavkhelidze, President, Academy of Sciences of Georgian SSR.

On behalf of the physicists of the Soviet Union and Georgia, let me congratulate you on your birthday. You are a Nobel Prize winner in the universal theory of electromagnetic and weak interactions. I think that not only I but many of your friends believe that you must have a second Nobel Prize as a humanist, a man who has created a highly spirited human institute here, an institute of theoretical physics. These are my best wishes to you and the wishes of all your good friends.

60.8 Prof. Yu Lu, Condensed Matter Research Group, ICTP.

First of all, we would like to heartily thank you, dear Professor Abdus Salam, for the enormous contributions you have made for the development of Science and Technology in the Third World. All of us sincerely wish you a happy birthday, good health and continuing success for the realization of the far-reaching plans you have blueprinted for scientists from the developing world.

Speaking in this auditorium, one cannot forget how difficult it must have been for you to create and nurture this unique Centre for science where particularly we from the developing world indeed feel at home and do not need to beg anybody. Twenty-six years ago the ICTP dream of Salam appeared impossible to many people as for the old good-hearted farmer in an ancient Chinese allegory who dreamed of removing mountains.

A long, long time ago there were two mountains in front of a village, one called Taihang, the other Wangwu. These two mountains prevented the village people from communicating with the others. An old farmer decided to remove these two mountains digging all by himself. He dug day and night. Some “wise men” laughed at him, saying, “How foolish you are! How can you remove the mountains?” In reply, the old man said: “If I die, my son will continue my work, and he will have his grandsons. Thus, generation after generation, up to infinity, the mountains cannot grow, so why can we not remove them?” The Lord was

deeply moved by his spirit and shifted these two mountains away. His fellow villagers were extremely happy.

We, people from the developing world are prevented from enjoying the latest achievements of Science and Technology, also by two mountains: poverty and backwardness. Who will be the Lord in our case, depends on one's creed. In my opinion, the Lord is embodied in the people of the developing world themselves, their conscious leaders, their friends, anyone who is sympathetic towards the Third World people and far-seeing enough to realize that a world with deepening gaps between the rich and the poor cannot be stable. The most important thing for us is the high spirit of this good-hearted old farmer. Professor Abdus Salam has set an excellent example in this regard. When he first proposed the International Centre for Theoretical Physics in the early sixties, many influential people opposed and laughed at him. Overcoming tremendous difficulties, he finally succeeded. His persistence and indomitable will were the crucial factors. Of course, the moral support of the international physics community, including the "Three Wise Men", really wise men in this case, the material support from the IAEA and UNESCO, and especially the generous support from the Italian Government, were essential for the success of this Centre. We are deeply grateful to all of you for this wonderful creation.

The twenty-six years of successful running of this Centre have more than justified its importance. Things have been changed significantly in the last twenty-six years. But, unfortunately, the gulf between the North and the South remains more or less the same. If in fact it has not become more pronounced, there are still hunger and starvation in the Third World. Even for the most developing countries like China, India and Brazil, the funding situation for the fundamental science is still miserable. For example, the total annual budget for the National Natural Science Foundation in China, the main funding agency in basic research, is about US \$20 million, i.e., about the same as the annual budget of the ICTP. Please remember, however, that China now has 1.1 billion population. Therefore, in spite of the progress made in some of the developing countries, the need for this Centre and other similar centers of Science and Technology does not fade away as time goes on.

Scientific excellence has always been the first priority of this Centre. I would like to give you only two examples about the level of the ICTP scientific activities of the last year. The first was the Conference on "Frontiers in Condensed Matter Physics" which had four Nobel Laureates, namely, Anderson, Rohrer, Schrieffer and Von Klitzing, as its speakers. The second was the Conference on "Topological Methods in Quantum Field Theory" organized by the High Energy Group at the ICTP. This Conference was also of the highest level of its kind in the world. The list of lecturers included three Fields medalists, namely Atiyah, Singer and Witten, as well as many world-class physicists. Moreover, we have succeeded in attracting to Trieste a group of very young scientists from the US and other developed countries who are playing a leading role right at the frontiers of research. This provides a unique chance for talented

young scientists of the developing world to talk directly and to collaborate with those who actually invented the new theoretical schemes and techniques, and "plug themselves in" immediately to the current competition of world science. The only alternative would have been to emigrate. This Centre has indeed played a key role in stemming the torrent of migration, especially during some difficult periods of many countries, for example, Argentina of the 70s as well as of today. The Centre is also helping some developing countries to build up a viable research community.

Unlike twenty-thirty years ago, modern physics relies heavily on computers. None of the developing countries can afford to buy supercomputers for this purpose. This means that physicists from these countries are stripped of the right to participate in this important field of research. Fortunately, there is a mini-supercomputer at the Centre. The Third World scientists can now use this facility, not only by coming here but even while staying at their home institutions via remote logging in. Of course, our facilities are far from sufficient to meet all the needs of the developing countries. An upgrading is urgently needed.

Science and Technology are a shared heritage of mankind. The Third World people – Chinese, Indians, Arabs, Persians, Turks, Afghans, Ethiopians, and Nigerians – did contribute a lot in the past, but not much recently. The present gap between the North and the South can be reduced if appropriate environment for Science and Technology is provided in the developing countries. The reduction of this gap is absolutely essential if we and our children are to live in a stable and harmonious world. The ICTP and similar centers built on the same principles are crucial elements for the construction of such a human globe. There were very few people in human history who consciously made such efforts to save human culture and to prepare the ground for future prosperity. As I was told by a Muslim friend, Khajeh Naseer Tusi of Persia was such a person. The observatory he built in Maragheh, Persia, where scholars from China up to Egypt worked under one ceiling, was in some sense a prototype of this Centre. This is something which will never be forgotten by the coming generations. Professor Salam's creation is another apt example. All of us from the developing countries wish you a long, healthy and fruitful life so that you can carry on your fundamental contributions to the human knowledge as well as your services for the well-being of science in the developing world.

60.9 Response to the Tributes and Messages by Dr. Abdus Salam.

I shall start with the story of the patriarch Abraham who is equally revered by Jews, Christians and Muslims. According to the Holy Book of Islam – the Holy Qur'an – Abraham, together with his son, is supposed to have founded the Ka'ba, the mosque in Makkah. While he was lifting big stones to build the structure, he prayed and said: "Oh Lord, I have settled from among my issue in a valley which is (all but) uncultivated but which enjoins Thine house which I am erecting for Thee so that they can stand and pray in front of Thee. Oh Lord, make

the hearts of men incline towards them and grant them the fruits of this earth so that they are grateful to Thee."

Thus, this prayer to incline men's hearts towards the people who resided in Makkah was made by Abraham himself.

I do not claim to live in Makkah, but I am part of the same tradition and certainly the prayer of Abraham has been heard so that so many different people from different walks of life have come together with their hearts inclined towards me. I feel very grateful to them all who have said such kind things about my role towards the founding of this Centre and the Third World Academy of Sciences.

I shall mention a few names to illustrate some of the points which have been made.

Professor Budinich said something of the Christian tradition must have rubbed off on me, which is very true. I have been saying to my Muslim friends and I will say it again that we must share the generosity of the Christian tradition if we are to be living on the same planet as they are. I shall repeat this message again. Fundamental faith is good because it leads you to the original faith which is set out in the Book. Together with fundamental faith, we must strive to be neither irrational nor intolerant.

I am grateful to the Presidents of the Royal Society and the National Academy of Sciences and the Chinese Academy and the Soviet Academy as well as the Accademia dei Lincei, for their kind and heartwarming words which they have sent me. They speak of the resolve on their part to help the Third World and those from the Third World who are listening to me should remember what goodness means – goodness of the people of Trieste, for example, in giving up their private privileges and in helping us from the Third World.

Someone spoke of the difficulties of setting up the Centre. The difficulty was not of the actual physical process of setting up the Centre. The difficulty lay in getting the ideas accepted in the first place. There was opposition from almost all the large industrialized countries, except Italy, Japan and the Nordic countries. After the first step was taken, the actual building of the Centre did not present difficulties. The City of Trieste took the matter in their own hands. This sustains the messages, which were read out today by Professor Budinich, Professor Bertocchi and Professor Fonda as well as by Dr. Hamende, the administrator of the Centre till recently. These men took the creation of the facilities to heart and they provided us with the basis of the most beautiful location in the world for a scientific center.

I see the Prince of Torre and Tasso and I must pay a tribute to his great father who was the first person to write to me regarding Trieste and its possibilities. I remember receiving a long letter which ended up with his signature. The signature extended over the whole page. I was very struck by that. I believe I still have that letter preserved in the archives of the Centre. I am also very grateful to the doctors in Trieste who have made it a profession to look after my health. I see Dr. Zambelli and Dr. Rocco who have looked after my broken arm, as well as Dr. Curri who has done so much to keep me in good form.

Coming to Italy has helped us materially. President G. Andreotti, whom I consider as one of my personal friends, came here one day and during that one day, he listened to us and he made up his mind that he was going to help the Third World Academy of Sciences to come into its own. He made an announcement [of a large donation] in this very hall. Right away, so that's real generosity, that's real helpfulness. And I must say the Government of Italy and the Italian people are to be commended for this because after all it is funds from their side which are coming to us for those from the Third World and we should be very, very happy with this arrangement.

There are several messages from Heads of State, from the President of Algeria, the Prime Minister of Italy, the President of the Ivory Coast, Crown Prince Hassan of Jordan, the President of Nigeria, the President of Sri Lanka, the President of Sudan, President Nyerere, ex-President of Tanzania, and finally, my personal friend, President Perez, the President of Venezuela. Some of them have been here and seen the way we have been working. They liked it and we liked them.

Before I conclude, I must pay a tribute to the Directors General of the IAEA, Dr. Sigvard Eklund and now Dr. Hans Blix, Mr. A. M'Bow and now Dr. F. Mayor of UNESCO, as well as Dr. Kouzminov and my personal friends, Dr. A. Kaddoura and Dr. A. Badran.

I must thank Professor Dalafi because Dalafi was the man who first tried to organize a celebration for my 60th birthday. That effort was quenched by myself at the last minute by telling Professor Marshak, Professor Witten and Professor 't Hooft who had come especially all the way from their home countries to speak and to honor me. I begged them to desist from that and they were persuaded. I could not persuade Professor Dalafi to stop his efforts this time because he told me that he was expecting President Andreotti – the *Numero Uno* of Italy. Unfortunately, President Andreotti could not come because of the Gulf War. However, President Andreotti, in spite of all the difficulties, has assured us that his spirit is with us and that we shall be able to get ICS successfully off the ground. He has promised to come and inaugurate ICS. ICS, the International Centre for Science, is the international technological arm of the Centre here. Its three parts are the International Centre for High Technology and New Materials, the International Centre for Chemistry, Pure and Applied, as well as the International Centre for Environment. This last will be in two parts – one here and one in Venice. The Venice part will deal with Marine Sciences. Professor Forti is in charge of the ICS.

I do not think I have left off anybody else. Ms. Zingarelli represented the staff. I must pay a tribute to the staff of the Centre, the staff of the ICS as well as to the staff of the Third World Academy of Sciences as well as to the scientific staff of the Centres. They are the people whom we should remember always and who have really done the work for which you have given me credit.

Professor Papic has to be thanked for his kind contribution and his analysis of what makes Salam tick. I do not agree with all the things which he said,

particularly when he spoke of the genius and the hard work. The hard work is certainly there but the genius may not be.

Anyway, I would like to say the following – to those of us who are from the Third World. I have learned through my life that sharing all the blessings which we have been vouchsafed – sharing and giving – these are the two things which have always sustained me. The Prophet of Islam said, “The hand which is above is better than the hand which is below.” This means that giving is better than taking. So, always be generous and share your blessings. That is one important lesson from all that one has been able to achieve.

It is a shock when one hears that one is sixty-five. I wish there were some way in which one could turn the clock back ten years at least and call oneself fifty-five.

Mr. Chairman, how old are you?

Prof. Salvini: I am older, yes, by six years.

Prof. Salam: Six years, good heavens! I would not have thought you to be more than sixty-one.

I shall finish with the story of Dirac's when we asked him if he would like his seventieth birthday to be celebrated in the Centre. He came to me and he was very angry with me, because I dared to suggest this. He said to me, “Do you really believe that I have finished off with physics?” – that's what he thought, that his 70th birthday celebration means that he was finished doing physics. I assured him that “No sir, your physics was as fresh as ever” – which was true. He was then reconciled to it, and he allowed us to go on with his 70th birthday.

So I have allowed Professor Dalafi to go on with my 65th birthday, in the hope that you don't think that I am finished with physics. I feel particularly proud of my last paper on the Role of Chirality in the Origin of Life.■

61

Excerpts from Selected Messages to Dr. Abdus Salam on his 65th Birthday

61.1 Dr. Frank Press, President, National Academy of Sciences, Washington DC, January 24, 1991.

I take great pleasure in anticipating your birthday on January 29, 1991, and extending my warmest congratulations to a distinguished Foreign Associate of this Academy.

A poet has said "For each age is a dream that is dying, or one that is coming to birth." Great accomplishments and bold visions have marked the various ages of your life, including winning the Nobel Prize and your role in founding both the International Centre for Theoretical Physics and the Third World Academy of Sciences.

What impresses me most as you approach your 65th birthday is that you continue to give birth to new ideas and to pour your energies into efforts that will benefit science and enrich the lives of people throughout the world. Besides your role as one of the luminaries of the world scientific community, you have truly been both statesman and humanitarian.

On behalf of the members of the National Academy of Sciences, I offer our very best wishes that the years ahead will continue to be a time of fruition for the wonderful seeds you have planted in science, education, and human development.

61.2 Prof. Zhou Guangzhao, President, Chinese Academy of Sciences, Beijing, January 26, 1991.

I am happy to know that January 29, 1991 will be your birthday. On behalf of the Chinese Academy of Sciences, I am sending you Happy Birthday wishes to celebrate this occasion. As an old friend of Chinese people, you have shown great concern over the scientific development of China. We will remember your contributions towards the cooperation between Chinese scientific community and the Third World Academy of Sciences.

61.3 Munir Ahmad Khan, Chairman, Pakistan Atomic Energy Commission, Islamabad, January 27, 1991.

Please accept our felicitations on your 65th birthday.

Your outstanding contributions to physics over a period of four decades and your passionate concern for the promotion of science in the Third World has won you world-wide acclaim. This is a source of great pride for us all. The International Centre of Theoretical Physics as well as the Third World Academy of Sciences, which you started and have been directing, continue to train and inspire thousands of scientists from the developing world to achieve international recognition in their fields. Your advice and guidance to the Pakistan Atomic Energy Commission particularly during its formative years contributed immensely to its development and success.

We wish you good health and many, many more years of creative and productive life.

61.4 Dr. Michael Atiyah, President, The Royal Society, January 28, 1991.

On behalf of your friends and colleagues at The Royal Society, I send you our best wishes on the occasion of your 65th birthday.

61.5 Dr. A. Tavkhelidze, V. Matveev, V. Rubakov, M.A. Markov, The Academy of Sciences of the USSR, Moscow, January 28, 1991.

It is a great pleasure for us to send you the most cordial congratulations and all the best wishes to you from so many of your colleagues and friends from the INR of the Academy of Sciences of the USSR at Moscow on the occasion of your 65th birthday. We wish you to know how great love and deep respect we feel to you. Generations of our theorists consider you as their teacher in elementary particle theory. We all share a great admiration for your tremendous contribution to the development of the worldwide international exchange in theoretical physics in both the West-East and North-South directions. Your outstanding achievements in science education and expansion of modern knowledge have been marked by many celebrated rewards including the Nobel Prize. We bow to you as the Founder Director of the International Centre for Theoretical Physics and the Founder President of the Third World Academy of Sciences which became the Mecca for theoretical physicists from all over the world. We are very grateful to you for your personal invaluable contribution to the development of scientific exchange of ICTP and INR at Moscow. We send to you our best regards and wish you good health and many, many years of active life in science.

61.6 Dr. Sigvard Eklund, President, International Atomic Energy Agency (IAEA), Geneva, January 29, 1991.

Heartiest congratulations on your birthday and the world-wide recognized achievements which under your wise and energetic guidance have been

accomplished by the Centre in fostering the progress of physics both in the developing and the developed world.

Wishing you good health and continued recognition of your successful efforts as up to now.

61.7 Professor A. Berbich, Permanent Secretary, Academy of the Kingdom of Morocco, Rabat, January 29, 1991.

I would like to take the opportunity of this joyful occasion of January 29, 1991, date of your 65th birthday to present to you my congratulations for your happy birthday.

I am delighted and so glad to have you among us as a dynamic member of the Academy of the Kingdom of Morocco.


I have the honor to see that through many decades of your life as a Founder Director of the International Centre for Theoretical Physics as well as the Founder President of the Third World Academy of Sciences and the Third World Network of Scientific Organizations, you enlightened with your contribution and the full radiance of your scientific knowledge more than thirty distinguished academies and societies.

May God bless you and Happy Birthday to you with a long and a healthy life. ■

A MAN OF SCIENCE
Abdus Salam, Nobel Laureate in Physics, 1979

THE GREAT DISTANCE FROM THE TURTLE

Julius Salas

Abdus Salam
 1926-1996

 Jagjit Singh

Abdus Salam: A Biography, by Jagjit Singh (Delhi: Viking Penguin India, 1992)

62

From a Life of Physics

Jagjit Singh

Science Writer, New Delhi

To write the life of a sage-scientist, who thanks to his extraordinary endowments, managed to bridge what C.P. Snow called the gap between the two cultures of Science and Humanities, thereby advancing not only physics to its present pinnacle but also taking in his stride the major problems arising from the impact of science and society, is an arduous and presumptuous task. Had Abdus Salam chosen to write his autobiography in conformity with the opinion of an earlier British sage of the eighteenth century, Samuel Johnson that every man's life may be best written by himself, the result would have been far more gratifying. Considering his mastery of the English language is as great as that of physics and mathematics, his autobiography would have been as perfect a work as he did in physics that won him the Nobel Prize in 1979. However, he is reluctant to write the story of his own life because he does not share the opinion of Samuel Johnson. ...

As I have had a long simmering admiration for the meteoric rise of a fellow countryman of the Indian sub-continent to the zenith of the firmament of world science, I have undertaken a task he has chosen to forswear. My sole qualification is that I had written, over a decade ago, a short piece popularizing his new theory unifying two of the four fundamental forces of nature, a feat as seminal now as James Maxwell's unification of electric and magnetic forces over a century ago. Since then I have had the honor and happiness of receiving from him, material for writing his biography.

Excerpt from Chapter VII: "From a Life of Physics"

In his address to the 25th Anniversary Conference on October 31, 1989, Salam recalled how the Centre was formally inaugurated in the Conference Room of the Trieste Jolly Hotel on October 5, 1964, and the progress it had made during the twenty-five years of its existence. He felt very proud of the kind of revolution the very existence of the Centre had brought about in the developing countries. He stressed his belief in science and its symbiotic ally technology, as an indispensable element for the development of the poor nations. He said, "Technology is a gift from God. After the gift of life it is perhaps the greatest of God's gifts. ... The most revolutionary aspect of science is its mobility. Anybody

Excerpt from "Prologue" in *Abdus Salam: A Biography*, by Jagjit Singh. New Delhi: Viking Penguin India, 1992, p. viii.

can learn it. It jumps easily over barriers of race and language. It took many generations of misery for the older industrial countries to master the technology of coal and iron. The new industrial countries of East Asia, South Korea and Singapore mastered new technology and made the jump from poverty to wealth in a single generation. ... Unlike most of our political leaders, we have first-hand knowledge of a business, which is not merely multinational but essentially international. ... As scientists we work every day in an international community. ... That is why we are appalled by the narrow-mindedness and ignorance of our political leaders of the Third World."

Salam then drew the delegates' attention to developments that had begun to occur in some English towns like Manchester about two hundred years ago. What was exciting about these little towns, he said, was that they brought science out of the academics and gave it to the people. They insolently repudiated the ancient prohibition: "Let nobody ignorant of geometry enter here," which Plato is said to have inscribed over the door of his academy in Athens. By bringing science out of the academic ivory towers, these little towns invented the Industrial Revolution, a hitherto unknown style of work, which grew inexorably from small beginnings and spread out from these towns until it had turned the whole world upside down. Benjamin Disraeli was the first politician to take the Industrial Revolution seriously. He perceived its social implications thirty years before he became the Prime Minister of his country. His novel, *Coninsby*, shows how he saw the Industrial Revolution through the eyes of its hero in its historical context as a social awakening as important as the intellectual awakening that occurred in Athens 2,300 years earlier. Unfortunately, said Salam, the political leaders of the Third World had yet to imbibe similar social awakening to the role of science as a catalyst of development.

Salam concluded his address by dwelling on physics and the excellences of life it brings in its wake. "There is no question," he said, "but that Physics is the science of wealth-production par excellence. This is because of its intimate relationship with the sophisticated high technology of microelectronics and microphotonics as well as sciences of space, fusion and the new high T_c superconductors. I have personally loved physics for the design of Allah's creation, which it unfolds. For example, I have dwelt on Astrophysics in my talk at the ESO-CERN Symposium on Astronomy, Cosmology and Fundamental Physics¹ on the theme that Particle Physics and Early Cosmology have become synonymous during the last few years. Allah's design is manifested by Solid State Physics, by Chemical Physics, which is at the heart of all Biology (by critical phenomena, even by chaos theory). I have not mentioned these subjects since I am beginning to study them only now.

"With string theory, fundamental Particle Physics has now changed its paradigm once again with the basic entities no longer appearing as point particles but as tiny strings which give rise to particles of spin 0,1,2,3,4 etc. in addition to

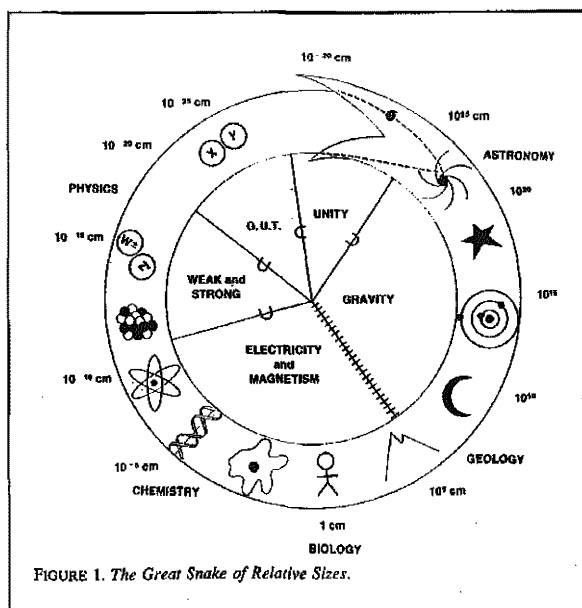
¹ This symposium was held from May 16-20, 1988, in Bologna.

spins $1/2$, $3/2$, $5/2$ etc. in the supersymmetric version. The Mathematics, which is needed, is the Mathematics of two-dimensional Riemann Surfaces; *four-dimensional* space and time arise as *secondary* concepts. For me, all this is tremendously exciting.

"There are a number of physical requirements which should be satisfied by a string theory:

- All source particles (quarks and leptons) plus messengers (like gluons, photons, W^\pm , Z^0) plus Higgs of the Standard Model should be comprised within this framework (with a minimum of new objects);
- It should be a geometrical theory since it must contain Einstein's theory of gravity as part;
- It should describe Einstein's gravity without any infinities.

"To achieve these three conditions would be a miracle, but this miracle seems to be happening, at least in 10-dimensional space-time where a *unique superstring* theory seems to have emerged, following the work of Green, Schwarz, Gross and others from the autumn of 1984. The important point is that Einstein's theory of gravity does emerge as a special sub-unit of the string theory. This justifies the picture of the Glashow snake eating its own tail i.e., microphysics at Planck scale (10^{-33} cm) coming together with macrophysics (10^{28} cm of the present Universe's size) described by Einstein's gravity theory. This, to me, is the ultimate unification. (Glashow drew the snake some time ago as the final desirable theory, while remaining skeptical about strings himself!)



Snake Theory

"The space-time which naturally emerges from this unique string theory is, as I said, ten dimensional. A Kaluza-Klein-like compactification of six *space dimensions* would then give the descent to the four dimensions of a realistic space-time. We shall also need to go down from Planck mass of around 10^{20} proton masses to 10^2 proton masses characteristic of W, Z particles and to 10^3 proton mass, characteristic of the electron mass.

"Unfortunately, the uniqueness in ten dimensions that made the string theories so attractive does not seem to hold when one goes over the four dimensions; a million or more theories (after compactification) appear equally viable. This is one of the theoretical dilemmas that faces string theory at present – the other dilemma being the basic experimental difficulty of building a collider with Planck energy. Such a collider must be ten light years long (even allowing for a performance factor – 1,000 better than the present accelerators. This factor is promised by the laser-plasma-beatwave concepts).

"Could strings really be the Theory of Everything (TOE) in Hawking's sense, combining all the known source particles, the quarks, the leptons, plus the messengers which we know of, plus the Higgs, plus their interactions? If so, would they represent the culmination of one's endeavors to unify the fundamental forces of nature? These are questions which time alone will resolve."■

63

Excerpts from Lectures in *Salamfestschrift*

A conference on "Highlights of Particle and Condensed Matter Physics" was co-organized in 1993 by Professors D. Amati, Steven Weinberg and Yu Lu, to honor Professor Abdus Salam on the occasion of his retirement as Professor of theoretical physics at the Imperial College of Science and Technology, University of London. It brought together scientists from thirty-two countries to honor a man who, in the words of the Editors, "has devoted all of his active life to the advancement of science around the world. ... Many of the friends and the former students of Professor Salam presented colourful recollections of their earlier meetings and work with him. It became apparent as the week went by, and memories surfaced more readily, that everyone had always enjoyed a productive relationship with Salam – he became a close friend, as well as a strong critic, of those he supervised and researched with." Dr. S. Randjbar-Daemi of ICTP in his Opening Address said that the Conference was organized "to honour Abdus Salam, who has been an active scientist for over forty years. In this remarkably long period, his interests have covered a wide spectrum of topics, ranging from the intricacies of renormalization theory in the early fifties, to the problem of the origin of life with which he has been recently involved. Professor Salam is one of the main architects of modern fundamental physics and, in particular, the Standard Model of Particle Physics." The following excerpts have been taken from the *Salamfestschrift: A Collection of Talks from the Conference on Highlights of Particle and Condensed Matter Physics*, ICTP, Trieste, Italy, March 8-12, 1993, edited by A. Ali, J. Ellis, S. Randjbar-Daemi. Singapore: World Scientific, 1994.

63.1 Professor Ahmed Ali of DESY, Hamburg, Germany.

I owe my scientific career largely to the generosity of Professor Abdus Salam. He helped me at a critical stage in my academic life, without which I would have definitely not been able to pursue a scientific career. I thank him sincerely for his timely help in rather difficult circumstances. I also take this opportunity to thank him for his scientific guidance and advice, which I have had the good fortune to enjoy in all these years. (p. 77)

63.2 Professor Steven Weinberg, Nobel Laureate in Physics, University of Texas, Austin.

I first met Abdus Salam in 1960, when he knocked on the door of the little cubbyhole that I had for an office at the Rad Lab in Berkeley. I had spent a fair fraction of my time as a graduate student in mastering Salam's analysis of

overlapping ultraviolet divergences, and then as a post-doc at Columbia in using Salam's result, that renormalization makes all integrals and all subintegrals however chosen superficially convergent, to show that the integrals actually converge. (I have always been proud of this proof, because it is the only place I know in physics where one actually needs to use the Heine-Borel theorem. Arthur Wightman had done me the great favor of reading through the manuscript, thus enabling me to claim that my paper satisfied a criterion that had been laid down earlier by Salam, that a notation should be understandable to at least two persons, of whom one may be the author. Understandable it may have been, but not elegant; Wightman told me that he could see blood on every lemma.) Knowing as I did the importance of Salam's contributions to renormalization theory, I was pleased and flattered that he had stopped by to say hello during his visit to Berkeley. It began a friendship that for thirty years has been a valuable part of my life in physics.

I think it was then that I proposed that I use a Sloan Fellowship to make a visit to London for several months the following year. Salam was good enough to offer the hospitality of his department at Imperial College, and I arrived in October 1961. By then both Salam and I had independently become interested in a new topic, spontaneously broken symmetries. I can't speak for Salam, but I know that I was at first confused about the role that broken symmetries might play in physics; I had some sort of idea that they would appear as approximate symmetries, something like the new $SU(3)$ of Gell-Mann and Ne'eman. Of course, it was not long before I learned better, through the work that Salam and I did that year at Imperial College (together with Jeffrey Goldstone as a long-distance collaborator), on the massless particles required by symmetry breaking. As everyone knows now, broken global symmetries in general don't look at all like approximate ordinary symmetries, but show up instead as low energy theorems for the interactions of these massless Goldstone bosons. (pp. 4-5)

63.3 Dr. A. Zichichi, CERN, Geneva.

One of the most important and original contributions to the advancement of physics is the invention by Abdus Salam of Superspace. The unification of all forces of Nature being his great dream, it is for me a great pleasure to contribute to his 70th anniversary celebrations by reviewing the present status of this new frontier of our Science.

Physics has been and continues to be a source of new ideas, new concepts, new problems. Our understanding of the foundations of Space, Time, Matter, Forces, Charges, has drastically changed. The Einstein four dimensional Space-Time has developed into a Superspace where the number and the properties of the original dimensions is now 10-bosonic plus 32-fermionic. These frontiers of Physics are dominated by the Salam dream: the existence of the Superworld.

Purpose of this lecture is to review the present status of this dream. A dream

with many appealing features: the boson-fermion equivalence, the unification of all gauge couplings and masses, consequently of all forces, including gravity, and the ultimate goal of discovering the Theory of Everything (TOE). A large number of papers has been published on this subject and many unjustified claims have been mixed with real achievements. In order to distinguish between these two classes clarity is badly needed especially when experimental consequences are involved. For example, to predict the energy level where the Superworld should show up is one of the most exciting problems of modern physics. The effort needed to implement a project, in terms of people and financial resources, is so vast that experimentalists themselves need to judge the value of a "prediction". It has often been said that the energy level needed to discover the first evidence of the Superworld is inaccessible with the present facilities: Fermi-Lab, LEP(I,II), HERA, Gran Sasso, SKK. The primary purpose of this lecture is to show that the Salam dream can be around the corner at present and near future facilities." (p. 187)

67.4 Dr. R. Delbourgo, University of Tasmania, Australia.

I was an undergraduate student of Abdus Salam at the Imperial College in 1959 leading to his supervisory role for my Ph.D. studies that blossomed into a full working relationship until about 1976, when I emigrated to Australia. This talk is a tribute to him for the help, guidance and friendship which he so generously offered throughout those years. Naturally his influence over my development has been enormous and, as you will see in this lecture, his many and varied physics contributions have shaped the way I think and act today. If you find anything attractive about what I shall describe presently, you may attribute it to the influence of Abdus Salam. ... I have many fond memories of those times of course ... Tom Kibble had been my official supervisor in 1960/61 but Salam took over the responsibility the following year, initiating me into the intricacies of the 'gauge technique' – a brand new way he'd found of handling the Green functions in gauge field theories. That work was written up in early 1964, by which time I was undergoing my postdoctoral apprenticeship at Wisconsin.

Salam may have sensed a keenness on my part to continue working with him and perhaps he found my assistance to be of some value. Anyway, when he offered me a job at the newly founded International Centre for Theoretical Physics (located in Piazza Oberdan then), I jumped at the chance of returning to Europe. The opportunity of collaborating with John Strathdee, my contemporary at Imperial, was an added inducement. Those early days at the Centre were rather exciting; it had just commenced operation and Salam fought extremely hard to make it a successful venture, something of which the world (and especially developing countries) could be proud. How he managed to carry out research at the same time, in such trying circumstances, I shall never know. John and I used to joke that Abdus did most of his work at airports or on aeroplanes since he was

constantly on the move, fighting tooth and nail to set the Centre on a firm financial footing. The fact that we are all housed in this magnificent complex is a monument to his energy and tenacity during those years.

In 1956, I moved back to Imperial as a lecturer and this allowed me to continue collaborating with Abdus, picking his brains and trying in some small way to learn the tricks of the trade. I hope that some of his insights and instincts have rubbed off on me. In any event I regard Salam as a true mentor and friend and I am especially honored to have been invited for such an important occasion. Except perhaps for John Strathee, it is unlikely that anyone present can claim to cover the range of interactions that I have experienced with him. (pp. 348-49)

63.5 Dr. Jogesh C. Pati, University of Maryland, USA.

Professor Abdus Salam is a great scientist, a humanitarian and a symbol for the Third World. ... Before I enter into the scientific part of my talk, I thought I would say a few words, befitting the occasion of this meeting, first about some rare qualities of Professor Salam and then about the way in which our collaboration started and grew. ... My collaboration with Professor Salam started in the summer of 1972. It lasted for over a decade and involved many exciting and memorable episodes. During this period, I used to come to Trieste for about two months every summer. The Adriatic Sea, the surrounding small mountains and the daily view of the setting sun have always been a source of inspiration to me. In part because of this but especially because of the warmth which I received from Professor Salam as well as from all the people at the Centre I have always loved to come back here again and again.

During the first six years, which was the most intense phase of our collaboration, Professor Salam also used to visit the University of Maryland during the academic year, often twice a year, for about a week each time. During these visits, the two of us would hide in the hotel room run by the University's Center for Adult Education, so that we would not be disturbed. There, we would spend the first few days in discussing physics and the last few days in writing papers. This was indeed a very productive period of our collaboration, marked with the joy of creativity and mutual appreciation.

During our collaboration there have been many letters, arguments, and even heated exchanges about taste and judgment in physics, but always in a good-natured spirit.

My great respect for Professor Salam is, of course, natural, in part because of his pre-eminence, but in part also because of our common Eastern tradition, which teaches us to respect the older, who is automatically taken to be the wiser. Because of this tradition, I still address him as "Professor Salam" rather than by his first name "Abdus". But what has touched me immensely over the years is that he also treated me throughout our collaboration with respect and affection. This served to establish a mutual bond between us which has lasted until today.

In our conversations, Professor Salam had some favorite phrases. For example, he would sometimes come up with an idea and if I expressed that I did not particularly like it for such and such reason, he would get impatient and say to me: "My Dear Sir, what do you want: Blood?" I would smile and say "No, Professor Salam! I would like something better."

Just as he would sometimes be impatient with me, there would be occasions when I would also get impatient with him and even say to him "Professor Salam! You just don't understand!" But, whether I was right or wrong, he never took it ill. In fact, because of these few exchanges, our collaboration became all the more strong. (pp. 368-70)

63.6 Dr. Peter West, Department of Mathematics, King's College, London, and Institute of Theoretical Physics, Chalmers University of Technology, Göteborg, Sweden.

I carried out my doctorate studies at Imperial College and had the good fortune to have Abdus Salam as my supervisor. When I began research, the paper of Wess and Zumino had induced many of Europe's leading physicists to work on supersymmetry and Abdus Salam and John Strathdee had just written their classic paper discovering superspace and super-Feynman rules. With such rapid progress being made it was not easy for a graduate student to achieve anything of significance, but despite his many commitments Abdus Salam was always ready to give helpful advice and encouragement. It was impossible not to be infected by his great enthusiasm for new ideas and the enjoyment he derived from doing physics. One came away from his office feeling that all was possible and that failure was only a temporary phenomenon.

Although it had been understood how to break supersymmetry using the classical potential, it was thought to be more desirable if it could be broken using radioactive corrections. Abdus Salam characteristically encouraged Bob Delbourgo and myself to systematically examine every possibility. He also, however, advocated that if all else failed one could always tell the truth. In this case, as I eventually found, the truth was that if supersymmetry was preserved classically then the effective potential vanished. It was this theorem which allowed others to observe that supersymmetry solved the technical hierarchy problem. (p. 452)

63.7 Dr. Ergin Sezgin, Texas A&M University, College Station, USA.

I have a deep sense of gratefulness to Professor Salam for more than a decade of continued support, encouragement and inspiration. ... I am delighted to have been involved with the activities of one of Professor Abdus Salam's most wonderful creations, the International Centre for Theoretical Physics in Trieste, in the capacity of a staff member for many years. I have very fond memories of

my Trieste years, working closely with Professor Abdus Salam and benefiting greatly from his profound wisdom. I have always been deeply impressed with his amazing ability to focus on the relevant issues, always getting straight to the heart of the matter. (p. 495)

63.8 Dr. Gerhard Mack, Institut für Theoretische Physik, University of Hamburg, Germany.

I came to Trieste in 1968. Abdus Salam had read my thesis, which dealt with dilatation and conformed symmetry in a Lagrangean framework. He congratulated me, saying that I had convinced him that conformal symmetry was not a symmetry for the crackpots. (It was suspect because it seemed to interchange spacelike and timelike points) ...

He invited me to Trieste and to work with him on conformal symmetry. A joint paper resulted out of this collaboration. But before that I was told that all the world was described by gauge theories, and I had better check whether the Langrangians of Yang Mills theories were conformal invariant. It was found that they were. ...

After my first few months there, the Centre moved from Piazza Oberdan to Miramare. And soon the place filled with unforgettable characters from all over the world. There was Daniel Akyeampong from Ghana, who was always in good spirits. His laughter could be heard through the halls and it brightened our days. There was M.O. Taha from Sudan who never took off his tie. There was Father Ryan from Ireland. He amazed the local girls who met him at the beach. He died later in a tragic mountain accident together with Bruno Renner. There was Nasrallah Nasrallah from Lebanon who chose to be called Michelangelo, because our teacher of Italian could not pronounce his name. There were also Israelis at the time, as Israel was still a member of UNESCO then. That led to some lively discussions around a ping pong table which I remember.

All the bachelors practically lived in the Centre. And we became very good friends, in spite of all the differences in cultural background, or just because of it. Wherever I go now in the world, I usually meet somebody who remembers me from Trieste.

I think this kind of understanding, solidarity and friendship between people from different cultures is what the world needs most in these days of global threat to the basis of human life on this planet. Powerful forces are needed to counteract the widespread human tendency to interpret any difference as a difference in value, fit to confirm one's own superiority. Otherwise hate will govern the world – look what is happening in former Yugoslavia.

For this reason I believe that the world needs 1,000 such Centres, in all fields of human endeavor, but with a clear will to separate knowledge from agitation and propaganda. It needs centers where people from different cultures can meet

and be friends. And the International Centre for Theoretical Physics in Trieste, which was created by Abdus Salam can serve as a model. (pp. 499-501)

63.9 Dr. M.J. Duff, Centre for Theoretical Physics, Texas A&M University, College Station, USA.

Twenty years ago, Derek Capper and I had embarked on our very first post-docs here in Trieste. We were two Salam students fresh from Imperial College filled with ideas about quantizing the gravitational field: a subject which at the time was pursued only by mad dogs and Englishmen. (My thesis title: *Problems in the Classical and Quantum Theories of Gravitation* was greeted with hoots of derision when I announced it at the Cargèse Summer School en route to Trieste. The work originated with a bet between Abdus Salam and Hermann Bondi about whether you could generate the Schwarzschild solution using Feynman diagrams. You can (and I did) but I never found out if Bondi ever paid up.)

Inspired by Salam, Capper and I decided to use the recently discovered *dimensional regularization* to calculate corrections to the graviton propagator from closed loops of massless particles: vectors and spinors, the former in collaboration with Leopold Halpern. [...]

When the deeds of great men are recalled, one often hears the cliché "He did not suffer fools gladly", but my memories of Salam at Imperial College were quite the reverse. People from all over the world would arrive and knock on his door to expound their latest theories, some of them quite bizarre. Yet Salam would treat them all with the same courtesy and respect. Perhaps it was because his own ideas always bordered on the outlandish that he was so tolerant of eccentricity in others, he could recognize pearls of wisdom where the rest of us saw only irritating grains of sand. As but one example of a crazy Salam idea, I distinctly remember him remarking on the apparent similarity between the mass and angular momentum relation of a Regge trajectory and that of an extreme black hole. Nowadays, of course, string theorists will juxtapose black holes and Regge slopes without batting an eyelid, but to suggest this back in the late 1960s was considered preposterous by minds lesser than Salam's.

Theoretical physicists are, by and large, an honest bunch: occasions when scientific facts are actually deliberately falsified are almost unheard of. Nevertheless, we are still human and consequently want to present our results in the best possible light when writing them up for publication. I recall a young student approaching Abdus Salam for advice on his ethical dilemma: "Professor Salam, these calculations confirm most of the arguments I have been making so far. Unfortunately, there are also these other calculations which do not quite seem to fit the picture. Should I also draw the reader's attention to these at the risk of spoiling the effect or should I wait? After all, they will probably turn out to be irrelevant." In a response which should be immortalized in *The Oxford*

Dictionary of Quotations, Salam replied: "When all else fails, you can always tell the truth." (pp. 553, 567-69)

63.10 Dr. T.W.B. Kibble, Blackett Laboratory, Imperial College, London.

I had the good fortune to join the Imperial College Theoretical Physics Group in 1959, just two years after it was set up by Professor Abdus Salam, accompanied by his erstwhile Ph.D. supervisor, Paul Matthews. It was a time of tremendous excitement and rapid progress, and Imperial was I believe one of the best places to be.

What I would like to do today is to recall some of the flavor of those times, to try to tell you what it was like. I want to review some of the highlights of the sixties from the perspective of my personal recollections, and to explain how the problems seemed at the time. You will not learn any new physics, but perhaps the story of our various misconceptions may serve as a cautionary tale.

Let me emphasize that this is not intended as a definitive historical account of the development of gauge theories. I am not equipped for such a task; I am not a historian of science and I have not tried to conduct a comprehensive survey of the literature. What I am aiming for is a much more personal story. I want to try to convey how it felt to be a member of that community and to participate in one of the most exciting developments in theoretical physics in our lifetimes. If in doing so I concentrate on those parts of the story with which I was most closely involved, I hope I may be forgiven for that degree of bias.

What was Imperial like around 1960? When I arrived, as Bob Delbourgo mentioned, we were still part of the Mathematics Department, occupying one corridor of the old Huxley Building which had once been part of a museum and is now again a wing of the Victoria and Albert Museum – a purpose to which it is much better suited! Our rooms were of very strange dimensions, often high and narrow, because they had been carved out of much larger areas. My office had only the top half of a window. The acoustics were such that we could hear every word of the lectures in the adjacent lecture theater, and no doubt the students could hear everything we said.

All the Ph.D. students were crowded into one big office, which was also where we met for tea and coffee. There were three permanent faculty: Salam and Matthews and John C. Taylor. I joined as a lecturer the following year.

Let me say at the start that it is a great sorrow that Paul Matthews could not have been here today, because of his tragic death five years ago. For many years, Imperial was Salam and Matthews. They made a superb team, exactly complementing each other's strengths and abilities. Paul would have loved to be here – and if he had been alive I am sure it would have been he rather than I who would be giving this talk.

One of the great things about our group in those early days was that we always had lots of visitors, both long- and short-term; our guests included Murray Gell-Mann, Ken Johnson, John Ward, Lowell Brown, Gordon Feldman and Steven Weinberg. Overseeing us all was Professor Salam's formidable secretary Bridget, of whom we were all terrified – all, that is, except Professor Salam! Personally, I always typed my own papers rather than face having to ask her to do it – and remember, there were no word processors then!

About a year after I arrived we moved into the Physics Department's new building. The then Head of the Department was another formidable and colorful character, Patrick (or P.M.S.) Blackett. Generally speaking, Blackett, having been brought up in the Cavendish Laboratory tradition under Lord Rutherford, was rather scornful of the value of theoretical physicists, but he knew a good thing when he saw one and persuaded Salam to join the rapidly expanding Physics Department, in what is now the Blackett Laboratory. There we had much better rooms and facilities.

What about Physics?

Many people have forgotten – and perhaps the younger among you never knew – that in 1960 field theory was widely regarded as very *passé*. Of course it had had its triumphs: renormalization theory had made sense of the old problem of ultraviolet divergences, and QED had been magnificently vindicated, with the predictions of the Lamb shift and the magnetic moment of the electron – it is still among the most impressively verified of all physical theories.

But field theory didn't seem to work for anything else, particularly not for the strong interactions. By 1960 the dominant ideology, especially in California from where I had just returned, was *S*-matrix theory. It was a very attractive philosophy. People always like to get something for nothing, even theoretical physicists – and it was amazing in fact how far one could go on the basis of a few very simple assumptions: relativistic invariance, unitarity, crossing symmetry and causality. The most radical version of the ideology, the self-consistent bootstrap, had as its aim to get all of strong-interaction physics from just these principles and nothing else. There were to be no elementary particles; everything was a bound state of everything else.

Of course, people did study field theory, often rather apologetically; they looked to field theory to provide a concrete model of how scattering amplitudes should behave, particularly to understand their complex analytic structure.

There were, however, a few places in the world where field theory was still studied unashamedly *qua* field theory. Imperial College was one of them. Harvard was certainly another; it is very noticeable how many of our visitors over the next few years were Julian Schwinger's students from Harvard. No doubt there were a few other places too!

Even we were not immune from the charms of *S*-matrix theory. Much of my early work was on dispersion relations, as indeed was much of Salam's. Salam and Matthews wrote an influential series of papers on dispersion relations for *K*-

meson-nucleon scattering. But at Imperial it was never a major theme. There were two dominant themes: symmetries and gauge theories. Both in a way had their origins in the tremendously successful concept of isospin (then still usually called isotopic spin, or isobaric spin by purists).

In the case of symmetries that origin is fairly obvious. The isospin symmetry between protons and neutrons had shown how two apparently disparate particles might be regarded as different states of a single fundamental entity, the nucleon. The symmetry was generalized to include Yukawa's mesons in an important paper by Nick Kemmer in 1938 – which is incidentally perhaps one of the first papers to suggest the need for a neutral current. Kemmer was a very influential figure in British theoretical physics in the immediate post-war period. He was Paul Matthews' supervisor in Cambridge and he was my Head of Department when I was a student in Edinburgh, succeeding Max Born in the Tait Chair of Mathematical Physics in 1953.

In the forties and fifties, as new particles proliferated, it was natural to try to bring some order into this chaos by enlarging the symmetry group beyond $SU(2)$, especially after the discovery of the new quantum number, strangeness.

One of the first students to work at Imperial on extended symmetries was Yuval Ne'eman. From his work on $SU(3)$, together with the independent work of Murray Gell-Mann, stemmed the eight-fold way ...

Salam himself made many important contributions then and later to unravelling these symmetries, but this was not I believe his first love. His real goal was always to find the ultimate theory that would describe the weak, electromagnetic and strong interactions, and even gravity – what we would now call a theory of everything. Discovering the symmetries provided important clues to this theory, and was therefore more of a means than an end in itself.

From an early stage, certainly well before I joined Imperial, Salam was convinced that the ultimate theory would be a gauge theory.

I myself caught that enthusiasm when I arrived at Imperial. I began working on gravity as a gauge theory, following in the pioneering steps of Utiyama, whose work in the fifties was mentioned the other day by Lochlainn O'Raikeartaigh. I showed that in that approach one rather naturally arrives at a generalization of the Einstein theory, involving non-zero torsion (as suggested long before by Cartan), interacting with the spin density. [...]

Postscript

That was by no means the end of the story. So far as electroweak unification was concerned, there were several important steps still to come: the GIM mechanism in 1970, 't Hooft's proof of renormalizability in 1971, the discovery of neutral currents in 1973, and of the W and Z bosons in 1983.

And, of course, Salam went on to even greater unification, for example in his work with Pati on lepton-hadron unification and with Strathdee on supersymmetry and superfields and on Kaluza-Klein theory; I could mention many others.

But although it is not the end of the story – indeed, will there be an end to the story? – it is a good place for me to stop. Before I do so, however, I would like to repeat what I said at the beginning. It was a tremendous privilege to be part of the team led by Professor Abdus Salam, and to participate in this voyage of discovery. I cannot imagine a place I would rather have been during those critical and exciting years. Many of us here, myself included, owe Professor Salam a great debt for the stimulus, support and friendship he has given us over many years. I hope that this meeting has helped in some ways to express that gratitude as well as our warm good wishes for the future. (pp. 592-95, 602) ■

64

Abdus Salam and the Shaping of Science

Nature, London

August 24, 1995

In 1974, Abdus Salam, not yet a Nobel prizewinner, in one of his final recommendations before resigning as the Pakistan prime minister's chief scientific adviser, suggested the convening of an annual forum where physical scientists from the developing world could meet and interact with their peers from the North.

Two years later, Salam led an international cast of physicists through the hills of northern Pakistan to attend the first three-week International Summer College on Physics and Contemporary Needs at Nathiagali. In the subsequent two decades, three hundred scientists, including six Nobel prizewinners have followed in Salam's footsteps and lectured on the frontiers and applications of physics to more than 3,000 participants from seventy-two countries.

The event is widely regarded as a successful example of North-South scientific cooperation. The organizers fittingly dedicated this year's twentieth anniversary meeting to Salam, the schoolteacher's son from a village in Punjab who shared the Nobel prize for physics in 1979 for his contribution to the theory of the unified weak and electromagnetic interaction between elementary particles and who, through the Third World Academy of Sciences and the International Centre for Theoretical Physics in Trieste, Italy, aspired to become a one-man bridge linking the fledgling science of the developing world with the advanced laboratories and research centers of the West.

Salam, nearing seventy and seriously ill, was unable to hear the generous public tributes to his life and work from, among others, his former students and peers, including Tom Kibble of Imperial College, London, as well as his intellectual successors, notably John Ellis of CERN (the European Laboratory for Particle Physics). There was even a belated appreciation from Benazir Bhutto, conveyed by her representative, Shahnaz Wazir Ali.

But, then, Salam was also spared the comments of those in his country of birth who continue to take a less generous view of his achievements, particularly for science in his home country. Despite his many achievements, Salam remains

Excerpts from "Science in Pakistan", *Nature*, Volume 376, August 24, 1995, pp. 634-35.

a controversial figure in Pakistan. Hounded for his "heretical" religious beliefs, criticized for his bias towards theoretical physics and castigated for rejecting Pakistan in favor of Europe as his base of operations, he has never quite managed back home to match his doe-eyed image in the West.

Between 1961 and 1974, Salam, as the country's chief scientific adviser, commanded the attention of three successive Pakistani leaders, including the military president Field Marshal Ayub Khan and the elected prime minister Zulfikar Ali Bhutto. No other individual has held such an influential position for so long, before or since. Yet his critics allege that there is little outside that realm of nuclear and elementary particle physics to show for Salam's thirteen years in the top science post. His period, they claim, was characterized by excessive idealism, a torrent of rhetorical statements and a failure to set and achieve realistic goals.

"Pakistan is not an efficient, developed country," says one of his peers. "It's a fact of life in this country that there is never going to be a massive injection of funds for science. But Salam never came to terms with this and always got angry and frustrated when the authorities rejected his larger-than-life schemes. Here, you have to make the best use of what you've got."

But Salam's friends and former students are keen to rally to his defense. At last month's Nathiagali meeting, several proudly recounted how Salam headhunted I.H. Usmani, a particle physicist turned bureaucrat, for the job of chairman of the Pakistan Atomic Energy Commission during its crucial formative years between 1960 and 1972. Together, the Salam-Usmani "dream-team" planned and set up PAEC's flagship laboratory, the Pakistan Institute of Nuclear Science and Technology (PINSTECH). The pair, according to Salam's biographer, Jagjit Singh, were also responsible for the purchase from Canada of a heavy-water CANDU-type 137-MW nuclear power plant for Karachi and a 5-MW research reactor for PINSTECH.

Salam is also credited with guiding the graduate physics program at Quaid-i-Azam University in Islamabad and the University of the Punjab and establishing and serving as founding director of the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), not to mention the International Centre for Theoretical Physics and the Third World Academy of Sciences.

But such "achievements" tend to draw criticism, not least from those who claim that Salam's successes turned Pakistan into a one-subject country: top of his class for theoretical and nuclear physics; but relegated to the remedial group for everything else. Wads of scarce funds, the critics allege, were lavished, on Salam's advice, to build and strengthen theoretical physics and the nuclear sciences, but at the expense of a balanced, coordinated university research policy.

Ishfaq Ahmad, the present chairman of PAEC, told during his own tribute how Salam arranged for five hundred Pakistani scientists and engineers to go to the United Kingdom and the United States for training in nuclear science. He also recalled with some satisfaction how Salam ensured that PAEC staff were paid higher salaries than their counterparts in the Ministry of Science. But even

Ishfaq, whose three decades with PAEC have turned him into a model of caution and diplomatic understatement, acknowledged that "we've had a lopsided development of science in the sense that the nuclear sciences are somewhat more advanced."

Pakistan's university physics departments are further monuments to Salam's influence. The physics department at both Quaid-i-Azam University and the UK built University of the Punjab concentrate research activity on theoretical physics, a legacy of Salam's involvement either as a lecturer, at the institution itself or as supervisor to Pakistani students at Imperial College, London, who later returned to Pakistan to take up jobs at these universities.

Only the University of Karachi broke the tradition by developing expertise in solid-state physics. Riaz Ahmad Hashmi, the departmental head, attributes this to the fact that the university was established in 1951, several years before the start of Salam's influence over national science policy.

Critics of Salam say his failure to make a bigger contribution to science in Pakistan also centers on his refusal to make Pakistan his permanent home. Salam was full-time professor of theoretical physics at Imperial College throughout his period as chief scientific adviser to the Pakistan government. In 1964, he added a third title as director of the newly established International Centre for Theoretical Physics in Trieste. [Jagjit] Singh maintains that the specter of intellectual death dissuaded Salam from settling down in Pakistan permanently. But his role as "adviser from a distance", says Singh, ultimately diluted his influence. [...]

Opinions about the full extent of Salam's views on Pakistan becoming a nuclear power remain divided. Although it is true that Salam always rejected the prime minister's offers to develop the bomb, Salam, in many other ways, had impeccable nuclear credentials.

He was an enthusiastic proponent of nuclear science in Pakistan, oversaw the development of PAEC and successfully lobbied for the purchase of the untried heavy-water CANDU-type nuclear power plant for Karachi instead of the light-water pressurized water reactor. The Canadians, realizing the plant's potential as a source of bomb-grade plutonium, cut off fuel supplies in the mid-1970s. Salam is also said to have advised Bhutto in 1973 to purchase the US \$300 million reprocessing plant from the French. The French, too, cancelled the order, under pressure from the United States, in 1978.

Salam continues to live the life of a self-exile. Despite his failing health, he remains a prolific writer. But visits to Pakistan are rare. Apart from a red-carpet reception by General Zia ul Haq following his receipt of the Nobel prize in 1979, this year's Nathiagali meeting was one of the few occasions in which the government publicly honored its most acclaimed scientist.¶

65

Professor Salam's Contributions in the Development of Science and Technology in Pakistan

Dr. Ishfaq Ahmad, Chairman,
Pakistan Atomic Energy Commission,
Islamabad

Professor Salam is a legend for the third world science. He is not only an eminent scientist recognized and honored by the world scientific community but is also an ardent advocate and a relentless crusader for development of science in the developing world. Salam's fervent quest for pursuit of basic research by the third world is interlinked with his desire to promote the scientific base of technology. He has always been passionately pleading that transfer of technology must be preceded or at least accompanied by scientific knowledge.

Prof. Salam is one of the main architects of whatever modern science exists in Pakistan today. His active association with development of Science and Technology in Pakistan dates back to 1955 when he was included in the Pakistani delegation for participation in the first UN Conference on Peaceful Uses of Atomic Energy in Geneva. Prof. Salam who was the most active member of the delegation acted as one of the scientific secretaries for the Conference. The cause of development of peaceful uses of nuclear energy in Pakistan was dear to Salam even at that time. He stressed upon the Pakistani delegation to go to Geneva with a draft plan for development of nuclear power in Pakistan. During the Conference he arranged a meeting of the Pakistani delegation with Sir John Cockroft, Director of Atomic Energy Research Establishment, Harwell, so as to find ways in which Britain could help Pakistan in peaceful uses of atomic energy. It was after participation in this Conference that Pakistan delegation submitted a detailed report to the Government of Pakistan for establishment of a nuclear research institute, construction of a research reactor and setting up laboratories for production and uses of nuclear isotopes in agriculture, medicine, and health. It was also proposed that immediately after installation of the research reactor, Pakistan should start planning for a nuclear power plant.

By the late 1950s Salam's important contribution in Elementary Particle Physics was already well-known in the educational and scientific circles of Pakistan. The University of Punjab conferred an honorary degree of D.Sc. on him

in December 1957.

In 1958, President Ayub Khan, met Salam for the first time at the inauguration of the Pakistan Science Conference at the University of Karachi. It was then that the President asked Salam to advise the government in matters related to science and technology. A year later, Salam was associated as Advisor to the Education Commission and a member of the Science Commission. In his inaugural speech at the first session of the Science Commission, on August 4, 1959, President Ayub paid the following tribute to Prof. Salam: "In the end, I must say how happy I am to see Professor Salam in our midst. His attainments in the field of science at such a young age, are a source of pride and inspiration for us and I am sure his association with the Commission will help to impart weight and prestige to the recommendations of the Commission."

During the same period the Government of Pakistan established a Department of Atomic Energy in Pakistan with Dr. Nazir Ahmad as its first Chairman. A vital contribution of Salam was induction of Dr. I.H. Usmani, as a Member of the Atomic Energy Commission and later its Chairman. Salam and Usmani met each other for the first time in a train compartment when they were traveling from Karachi to Multan. Salam had heard about Usmani but did not recognize him by face whereas Usmani probably knew Salam. According to Salam's own account, Usmani offered him to share his meal and they talked about the Nobel Laureate G.P. Thomson whose memories both cherished. Thomson was Usmani's supervisor at Imperial College and Salam valued his association with the Nobel Laureate. Usmani had then just assumed the position of Joint Secretary to Government of Pakistan, in charge of mineral development and the mineral survey of Pakistan. Salam immediately realized that Usmani was amply suited to play a vital role in the development of science and technology in Pakistan. After a few days when Salam happened to see President Ayub Khan, and the Finance Minister M. Shoaib, they sought his opinion about the most suitable person to head the Atomic Energy Commission. Salam had no hesitation in recommending the name of Usmani, who was immediately appointed a Member of the Atomic Energy Commission with the tacit understanding that he would take over as Chairman when Dr. Nazir Ahmad retired.

One of the first actions of Usmani as Chairman was to plan for sending out about five hundred physicists, mathematicians, health scientists, and biologists abroad. Salam helped Usmani not only in the formulation of this plan but also in its execution by helping in the placement of these scientists and engineers at the best academic institutions in the US and UK.

In 1960, Prof. Salam conceived the idea of establishing an International Centre for Theoretical Physics under the aegis of IAEA. He proposed that Pakistan Atomic Energy Commission acts as a host for this Centre. Using the tremendous influence he enjoyed, Salam convinced President Ayub Khan about the usefulness of the proposed Centre. The proposal was formally approved by

the Government of Pakistan who also issued instruction for allocation of the necessary funds for this purpose. However, Pakistan lost its bid for the Centre to Italy which offered better conditions for hosting the Centre.

In 1961, Prof. Salam persuaded Prof. J. Wiesner, President Kennedy's Science Advisor to send a team of University scientists, hydrologists, agriculturists led by Dr. Roger Revelle to advise Pakistan on the problem of water-logging and salinity. The problem had been so acute that about a million acres of land were passing out of cultivation every year during 1950 to 1960. American experts made some useful suggestions for the solution of this problem.

Professor Salam is also responsible for leading Pakistan into "space age". His proposal (co-authored by Dr. Usmani) to set up a committee to probe space and upper atmosphere was approved by the Government in September 1961. On June 7, 1962, a team of PAEC scientists and technologists successfully launched a two-stage weather rocket (Rehbar I) from Sonmiani Rocket Range, thirty-five miles west of Karachi. This was followed by the launching of Rehbar II on June 11, the same year. The program was executed by Pakistan Space and Upper Atmosphere Research Committee, under the Chairmanship of Professor Abdus Salam. SUPARCO is now a full-fledged organization and pursuing a program of peaceful applications of space technology.

Professor Salam also actively worked with Dr. Usmani in establishing PINSTECH and installing the first nuclear power plant of Pakistan, KANUPP. He was personally involved in selecting the present site for PINSTECH. The respect which he enjoyed in the Pakistan Atomic Energy Commission is obvious from the fact that Dr. Usmani invariably requested Prof. Salam to preside over meetings of the Commission which are normally chaired by its Chairman.

In December 1971, Zulfikar Ali Bhutto took over as President of Pakistan. Because of the international recognition that Salam enjoyed, Bhutto decided that Salam would continue to serve his government as Chief Scientific Advisor. However, it was decided to replace Dr. Usmani by Mr. Munir Ahmad Khan as Chairman PAEC. After Munir Ahmad Khan's appointment, Prof. Salam continued his active association with PAEC and guided the Commission in various areas of its activities. On his advice, the eminent theoretical physicist, Prof. Riazuddin was appointed Member (Technical) of the Commission. The Nathiagali Series of Summer Colleges which have been held regularly since 1976, was also Salam's idea.

On the occasion of the First Islamic Conference held at Lahore in 1974, Salam put forward a proposal for the creation of a Foundation by Islamic countries with the objective of advancing science and technology. He proposed that the Foundation work with an endowment of one billion dollars and the

proportion of endowment fund to be contributed by each sponsoring country being fixed fraction of the export earning of each country. Unfortunately this proposal of Salam still continues to be under active consideration of the Muslims and only a paltry sum has been donated to realize the idea.

In 1974, Professor Salam resigned from the post of Chief Scientific Advisor to the Prime Minister and formally ceased to be a member of Atomic Energy Council. Mr. Rafi Raza, then Minister for Production, Industries and Town Planning, opening the 7th meeting of the Council, held on December 23, 1974, eulogized the services of Professor Salam to the Commission and "regretted formal ending of his association with an institution with which he had been connected from its very inception." He clarified that "though the resignation of Professor Abdus Salam had been accepted in principle by the government, yet it was hoped that he could keep himself associated with the cause of science in Pakistan. He wished that Professor Abdus Salam continued to be the Advisor or Consultant for rendering all possible assistance either at his own discretion or at the request of Chairman PAEC." Other members of the Council also expressed their deep sense of appreciation to the services rendered by Professor Salam for the cause of science in the country in general and atomic energy in particular. Even after he formally left the post of Chief Scientific Adviser, Professor Salam remained in close contact with the Pakistani scientific community and spared no efforts to further the cause of science and scientists in Pakistan.

The greatest moment of triumph for the Pakistani scientific community, in fact the whole nation, was in 1979 when Salam was awarded the Nobel prize. The Government of Pakistan conferred the highest civilian award, Nishan-i-Imtiaz on Salam for his outstanding contribution in science. Prof. Salam also instituted Salam Prize for the young Pakistani scientists.

Lastly, I would like to say a few words about the versatility of Salam. Apart from being an eminent scientist, he has been a very competent administrator, a prolific writer, a forceful speaker and a great communicator who felt at equal ease conversing with scientists, bureaucrats, planners, and political leaders. Another striking feature of Professor Salam's personality is that although he had great dreams for science and its development, he lived a very simple and unpretentious life. One was also struck by the great warmth and zeal with which he articulated his views and convictions. Professor Salam who brought sunshine to the Third World Science, is now passing through the autumn of his life. We all wish him a long and happy life. ■

66

Abdus Salam, Lone Pakistani Nobel Laureate,
Turns Seventy

Prof. Anis Alam
Department of Physics,
University of the Punjab, Lahore

Abdus Salam, the greatest scientist that Pakistan has produced, turned seventy on the 29th of January 1996. He has brought fame and glory to the name of Pakistan by winning the 1979 Nobel prize for physics. As an undergraduate student of physics, I was often intrigued by questions raised by quantum theory; wave-particle duality and resulting indeterminacy in measurements. Prof. Abdus Salam was already famous and I wished to do research at the fundamental level. I got the first glimpse of Prof. Abdus Salam's generosity and concern with Pakistani science in the autumn of 1964. I had taken the examination for M.Sc. Physics at the Punjab University. The result had not yet been declared. However, I had been awarded a Central Overseas Training Scholarship, for post-graduate studies, by the Punjab University. There was still the question of my admission. Prof. Hameed Ahmad Khan, Vice-Chancellor of the Punjab University, talked to Prof. Abdus Salam on phone about me. Prof. Abdus Salam disregarded all formalities and admitted me to the D.I.C course in Theoretical Physics at the Imperial College of Science and Technology, London. I was thus able to join the Imperial College in the first week of November 1964. I was unlucky not to be his student that year. He was busy setting up the International Centre for Theoretical Physics in Trieste, Italy. When I returned to Punjab University after obtaining my Ph.D. in 1967, I faced problems that most researchers of developing countries face on return; lack of environment friendly to pursuit of academic work. Prof. Abdus Salam advised me to be patient. Subsequently, he has provided me solace and help to survive as a working physicist in Pakistan for over the last twenty-five years.

Abdus Salam is the most acclaimed and honored Pakistani physicist in the world. He has led an eventful life. His accomplishments are great. He is not only one of the greatest scientists of the century, but also a multifaceted personality. His reflections on science, technology, education, history, philosophy, religion, economics, politics, culture, and general problems of underdevelopment in the Third World are extremely important, thought-provoking and very valuable.

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He is the first Pakistani to join the list of those celebrated scientists who have worked at the most basic of the questions concerning the physical world. What are its building blocks? What are the forces that bind the primordial entities into more and more complex structures that we observe in nature? Is there an underlying structure for the diversity one finds in nature? Are there some general underlying principles that bring an order into otherwise chaotic reality? Could one find one general principle that would order all reality?

Abdus Salam is among the latest to join the illustrious company of scientists, who have discovered the fundamental laws governing the physical universe: the English Newton, discoverer of the law of universal gravitation; the French Coulomb, discoverer of the universal law between electric charges; the Japanese Yukawa, discoverer of the law governing force among nucleons inside the nucleus; and the Italian Fermi, who discovered the weak nuclear force.

Scientists have also tried to understand the complexity and diversity of nature in terms of a minimum number of building blocks and a minimum number of forces between them. The first of these was again the great Newton who postulated that the same laws of mechanics and gravitation as operate on the earth are also operative in the heavens. He thus shattered the duality of laws; terrestrial and celestial which had been accepted since the time of Aristotle in the 6th century BC. Then there was the great Scotsman Albert Maxwell, who unified the electric and the magnetic forces through his laws of electromagnetism. Maxwell was followed by the great Albert Einstein who spent the last thirty years of his eventful life for a unified law to explain everything.

Salam is one of those who have successfully made the first advance towards achieving Einstein's goal; unifying all forces of nature into a single one. He succeeded in unifying two of the four fundamental forces into one.

He was able to prove that the weak nuclear and the electromagnetic forces are two manifestations of a single force, the electroweak force. Two American physicists, Steven Weinberg and Sidney Glashow also arrived at the same conclusion independently. All three shared the Nobel prize for physics in 1979.

What, however, distinguishes Salam from most fellow scientists is his very strong feeling for humanity, best exemplified by the following lines from Omar Khayyam which he is very fond of quoting:

Ah love! Could thou and I with fate conspire
To grasp this sorry scheme of things entire
Would not we shatter it to bits – and then
Remold it nearer to the heart's desire.

Throughout his working life, Salam has been driven by his desire to create a better world. It would have been far easier for him to keep busy with his scientific researches, accept Professorial chairs in prestigious seats of learning,

make life comfortable for himself and his family. But being strongly aware of his social being, hence of his social responsibilities, he took the more hazardous road. All his life Salam has given as much importance to social concerns as to his scientific work. His life is a shining example of a person living a full professional life while fully alive to societal obligations. [...]

Salam realized very early that the problems of poverty, disease, malnutrition, sanitation, hygiene, and of general underdevelopment, faced by the developing countries including Pakistan cannot be solved unless these countries become literate, acquire scientific knowledge and use it for economic development. He also realized early that if he has to make any impact he will have to persuade the people and the governments in the developing world to understand the importance of science in the economic development. Once he became famous and began to be accorded respect and attention he started using his considerable prestige and authority for the cause of education and science in the developing world. [...]

Another problem of great concern to Abdus Salam has to do with world peace. Along with such great scientists as Einstein, Salam has always believed that with the development of knowledge in general, and of sciences in particular, it has become possible for all inhabitants of the planet Earth to enjoy a life of comfort, prosperity, and peace. The world could live without wars. Science has provided the means to increase productivity, lessen the use of materials and energy to levels unheard of in earlier periods of human history. Small nations like Sweden, Finland, Holland, Belgium, Switzerland, Singapore could provide their people with the highest living standards prevailing anywhere without waging wars on others. But they have achieved all that by cultivating sciences and using them for general economic and social development.

He is appalled by the enormous amount of resources which the world spends on armed forces. He is disturbed by the wastage of enormous human and material resources spent on the development of new weapons systems, nuclear as well as conventional. He has joined forces with other prominent scientists in the Pugwash movement to campaign for the abolition of nuclear weapons and for general disarmament. His association and work with Pugwash movement finally resulted in the reversal of nuclear armament with the signing of various nuclear arms reduction treaties. In 1995, Pugwash movement was jointly awarded the Nobel Peace prize with Prof. Rotblat as co-recipient.

When the US government announced an extremely ambitious program for developing antiballistic missile system in the early 80s, Salam, anticipating a spurt in the arms race, joined a campaign with other prominent scientists to bring some sanity to this program. This so-called Strategic Defense Initiative (SDI) was to cost almost 1,500 billion dollars by the year 2000. Salam argued along with many other respected physicists, the fallacy of the very idea behind the

strategic defense initiative. As a result of the analysis and criticism by US scientists and Salam, the SDI program has been greatly curtailed in recent years.

In a number of articles and on various important world forums, Abdus Salam has advocated the diversion of human and material resources from war efforts to the welfare of mankind. Just a fraction of the amounts spent on arms diverted to the cause of human resource development could, according to his arguments, alleviate much of human suffering from malnutrition, disease, and unemployment.

Abdus Salam's effort for world peace and global disarmament have been widely recognized. In 1968, he was awarded the Atoms for Peace Medal and Award. In 1981, he was awarded the Peace Medal by Charles University, Prague. In 1986, he was awarded the Premio Umberto Biancamano Medal and Award by an Italian Foundation. He has been a long serving member of the Stockholm International Peace Research Institute (SIPRI).

It may be interesting to point out that Salam has used the considerable amounts from his various awards and prizes to establish funds and foundations for the advancement of science in the developing countries.

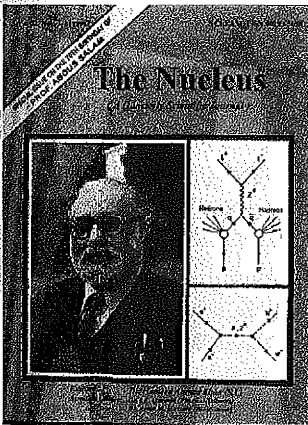
There have been few men of science born in what is now generally called the Third World. Salam is perhaps the only one who has made contribution at the fundamental level of our understanding of basic physical forces which have given rise to the universe and keep it going.

He is unique in another respect. He is proud of his third world background and Pakistani origin. He has continued to draw sustenance from his philosophical, cultural, and religious roots while keeping himself in the forefront of international scientific community. He is a deeply religious man, who finds no contradiction between his scientific investigations and his religious beliefs. However, he firmly believes that religion and science should not be mixed. They should be treated separately. He is critical of attempts to read modern physics into ancient scriptures. In his view such attempts disgrace the scriptures that have a deeper meaning. Scientific concepts change while scriptures cannot. So problems arise when the veracity of scriptures is sought in the theories of science.

Dr. Salam's last public meeting in Pakistan, was in Lahore in February 1988. He came on the invitation of the Faiz Memorial Committee to deliver the Faiz Memorial lecture. He was received with great enthusiasm. The hall where he gave his talk was packed to capacity. He was listened to with rapt attention. He deliberated on the whats, hows, and whys of the physical universe, and its evolution. He also discussed the situation regarding science in developing countries in general and Pakistan in particular. He observed that what differentiates the developed world from the underdeveloped, is science and technology, not wealth. The developed world creates science while the developing world largely consumes it. Salam pleaded with his audience to master

science because their salvation lies in that effort. He told them that even in a developing society it is possible to learn and practice science at the highest level. His own example has demonstrated that people in developing worlds can, not only just learn it, but also excel in its practice and be even its creators.

We need heroes and role models. In an age where long-standing idols have toppled and giants have been found to have feet of clay; where acknowledged leaders preach hatred, intolerance, and violence in the name of religion; when truth gets trampled daily on the altar of expediency, we need models of compassion, integrity, truthfulness, and humanity. Abdus Salam is such a personality that Pakistani youth ought to emulate. Let us all compliment Abdus Salam on his seventieth birthday, for leading a very fruitful life that has brought fame and glory to Pakistan.■



70. Title of *The Nucleus*



71. Hans Blix



72. Federico Mayor

67

Some Condolence Messages from ICTP Files on Dr. Abdus Salam's Death (1996)

67.1 Dr. Hans Blix, Director General, International Atomic Energy Agency (IAEA), November 21, 1996.

On this saddest of occasions, I wish to join the scientific community by expressing my sincere condolences in connection with the passing away of Nobel Laureate Professor Abdus Salam. As a pioneer of Theoretical Physics, he founded with the IAEA the International Centre for Theoretical Physics which under his leadership has helped innumerable scientists from developing countries to keep up with the latest scientific developments and to continue their work to promote scientific progress.

67.2 Dr. Federico Mayor, Director General, UNESCO, Paris, November 22, 1996.

Professor Salam will forever be remembered as a man of exceptional achievement and human qualities. ... He was an outstanding science leader. ... UNESCO and I have lost a friend and we shall greatly miss his wisdom, guidance and encouragement.

67.3 Prof. Zhou Guangzhao, President, Chinese Academy of Sciences, Beijing, November 22, 1996.

It is with great shock and sadness that we learnt the passing away of Prof. Abdus Salam. ... The passing away of Prof. Abdus Salam is a great loss to the world scientific community and particularly to the Third World scientific community. His enduring effort in promoting the progress of science in the Third World countries as well as his friendship towards the Chinese people and Chinese scientists will be remembered forever.

67.4 Dr. R. Amrollahi, Vice President of the Islamic Republic of Iran and President of the Atomic Energy Organization of Iran, Tehran, November 23, 1996.

This loss is not confined to the premises of the ICTP but belongs to the international community in general and the scientists of the developing countries in particular. He was and shall remain an inspiration to us all and we should repay our debts to him by following his path and his visions.

67.5 Sir Arthur C. Clarke, Chancellor, University of Moratuwa, Sri Lanka, November 25, 1966.

I had known [him] well owing to our membership of various international scientific organizations.*

67.6 Prof. Ayhan O. Cavdar, President, Turkish Academy of Sciences, November 25, 1966.

On behalf of the Turkish Academy of Sciences and the Turkish scientific and academic community, I express deep sorrow and sincere condolences at the loss of Professor Abdus Salam, most distinguished scientist, and tireless promoter of scientific values for the benefit of humanity. His successful example will continue to inspire us, and to live in the institutions and traditions he started.

67.7 President Julius Nyerere, Chairman of South Commission, Former President of Tanzania, Dar-es-Salaam, November 26, 1966.

Abdus Salam was a very special human being, who combined a commitment to pushing forward the frontiers of science with a deep sense of responsibility to the countries and peoples of the developing world.

The South Commission Report would have been very different – and much less useful – without his contributions to the many discussions held and his constant reiteration of the importance of promoting the development of Science and Technology within developing countries.

Professor Salam was also a person who won respect and affection from all those who came to know him through the South Commission. We were all saddened by his progressive illness since 1988, but also inspired by the example of his great courage in facing (and for a long time overcoming) the increasing physical disabilities from which he suffered.

67.8 Dr. M.J.A. Larijani, Director, Institute for Studies in Theoretical Physics and Mathematics (IPM), Tehran, Iran, December 4, 1966.

Abdus Salam continues to live through his legacy. The scientific community in Iran and in particular IPM and its scientific staff have been direct beneficiaries of Professor Abdus Salam's many deeds of generosity. His vision, leadership and pioneering ideas continue to guide and inspire us in our endeavor to develop science and a scientific community in our country.

67.9 Dr. G. Thyagarajan, President, International Council of Scientific Unions, Chennai, India, December 5, 1966.

Professor Salam strode the world science scene majestically and most admirably. Third World scientists looked up to him for inspiration and guidance.

* In a personal letter Sir Arthur wrote to me: "In the context of Buckminster Fuller's and your *Humans in Universe*, your friend [Professor Salam] was a good and beautiful human in the universe." – Anwar Dil

His many prompt initiatives to give stature to Third World scientific organizations will be remembered and recognized and respected forever. ... Although Professor Salam was in indifferent health during the last four years his scintillating intellect assured us that he was going to be with us for many, many more years. However, that was not to be. His death is premature and removes from the world scene a gentleman scientist of extraordinary and unparalleled qualities and abilities.

67.10 Dr. Fawzi Gharaibeh, President, University of Jordan, Amman, November 30, 1996.

Indeed, Professor Abdus Salam's death is a severe blow to his friends and colleagues and his immense interest in promoting science, research and education in Third World countries earned him the respect and admiration of all those who worked closely with him. All of us here, at the University of Jordan, remember very vividly his sterling efforts in putting the agreement between our two institutions into action, and pursuing its implementation for our mutual benefit. His work lives on and he shall be for long missed by everyone.

67.11 Dr. Dhruba Man Singh Amatya, Vice Chancellor, Royal Nepal Academy of Science and Technology, Kathmandu, December 5, 1996.

We Nepalese have lost one of our most sincere friends and well-wishers.

Professor Salam's visits to Nepal during participation in Summer School of Physics, will be long remembered. His suggestions and advices during his visits have helped a lot for creating conducive environment for the development of Science and Technology in Nepal. His encouragement and assistance for the establishment of Third World Academy of Sciences (TWAS) Award in Nepal is unforgettable.

I had personally seen and listened to him in Geneva in 1962 during the United Nations Conference on Science and Technology when he delivered a brilliant speech.

67.12 Dr. Heitor Gurgulino de Souza, Rector, United Nations University, Tokyo, December 5, 1996.

It is with profound shock and regret that I learned today of the death of Professor Abdus Salam, a friend of the United Nations University, whom I had the pleasure of meeting before his retirement.

His passing away is a great loss for the academic and scientific communities as he had significantly contributed to the progress of science, especially in developing countries. It is also a great loss for the United Nations University for he had not only been involved in its establishment but had also acted as Chairman of its Advisory Committee for many years.

All the staff of the United Nations University join me in expressing our deepest sympathy.

67.13 Dr. Salha Sankar, Minister of Higher Education, Syrian Arab Republic, Damascus, December 12, 1996.

On behalf of the Ministry of Higher Education and the other two Syrian institutions, members of TWNSO, The Scientific Studies and Research Center, and the Atomic Energy Commission, I express to you our deepest sorrow and sincerest condolences for the passing away of Professor Abdus Salam.

Professor Abdus Salam will forever be remembered as a great scientist of the Third World and its leading proponent of Science and Technology based development. His unswerving faith in this cause and his dedication and his life long struggle to promote it will provide inspiration for generations to come to all scientific communities in the Third World seeking to contribute to the national development of their countries.

67.14 Dr. Ruth Zagorin-Hopper, Chairman, The International Federation of Institutes for Advanced Study (IFIAS), Toronto, Canada, December 19, 1996.

I wish to express on behalf of all in IFIAS our great sadness. We are all very conscious of the many contributions that Abdus Salam has made to humanity, as well as to physics, particularly through the role he played in the creation of ICTP and the Third World Academy of Science and its related organizations.

But Abdus Salam also holds a very special place in the history of IFIAS: from his presence at the 14th Nobel symposium, where the concept originated; through the meetings at Serbellini, where it was given form; to its Founding meeting in October 1972, which he hosted. Now ICTP continues to be one of the foundation stones on which IFIAS knows it can build.

67.15 Dr. Thomas R.R. Odhiambo, Director, The International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya, December 20, 1996.

It is with great sorrow and a sense of deep loss that we have just learnt of the death of Professor A. Salam – a great scientist, a great humanist, and simply a visionary man. He leaves a yawning gap in our thinking lives.

We mourn him; and wish him a peaceful place in Almighty God's presence!

67.16 Dr. Victor Latorre, Director of Multiciencias, Lima, Peru, November 21, 1996.

I write with a heavy heart at hearing of Prof. Salam's passing away.

He was a tremendous source of inspiration for us all. It was a source that for over thirty years drove us in the right direction. I can even hear his powerful speech resonating in Miramare when I first met him. He changed my life and I am proud of it. He set Multiciencias goals, gave it its initial momentum, and helped it along the way.

He would like us to move even faster and do our work even better.

67.17 Dr. Rohan H. Wickramasinghe, Director, Institute of Tropical Environmental Studies, Colombo, Sri Lanka, November 22, 1996.

Professor Salam, who honored Sri Lanka by visiting and presenting lectures in this country, was an inspiration to the scientists of this country. Furthermore, in addition to his immense contribution to human knowledge, he will always be remembered with especial respect and affection by scientists of the Third World and the peoples of South Asia for his determined efforts in support of their further scientific development. We are truly saddened by his passing away.

67.18 Dr. Asghar Qadir, Professor of Physics, Quaid-i-Azam University, Islamabad, November 22, 1996.

This is to convey to ICTP my deep sense of personal loss at the demise of Prof. Abdus Salam. Despite his having been ill for so long, one felt his protective presence and feels lost and rudder-less after him. Not only Pakistan, not only the Third World, but the entire World, has lost a true friend who cared for its welfare – not abstractly but with a deep personal concern. The scientists of the Third World will only now begin to realize their enormous debt of gratitude to this man who fought for their interests. We, of Pakistan, can be proud to have produced such a man for the rest of the World but can hardly hope to produce another such.

67.19 Dr. M.S. Swaminathan, M.S. Swaminathan Research Foundation, Chennai, India, November 25, 1996.

It is with very great sorrow we learnt the sad news about the demise of Prof. Abdus Salam. We will never see a person of his concern and commitment for improving the quality and effectiveness of Third World science. He was one of those unique theoretical scientists who brought their enormous vision and wisdom to bear on the day to day problems of Third World science.

67.20 Dr. R. Ramachandran, Director, The Institute of Mathematical Sciences, Chennai, India, November 25, 1996.

The members of the Institute of Mathematical Sciences, Chennai, gathered on 22nd November at 5.00 p.m. to pay homage to Prof. Abdus Salam.

The meeting recalled his role as one of the architects of our modern understanding of the fundamental forces of nature. During his long and brilliant career, Prof. Salam was at the forefront in an era when tremendous advances took place in high-energy physics. His contributions, particularly to the theory of electromagnetic and weak forces, place him in the ranks of the great scientists of all times. ...

Prof. Salam had a long association with many scientists from India and had a warm appreciation of this country's scientific institutions and achievements. The meeting recalled Prof. Salam's warmth and friendliness in all his personal interactions, which many of the members of this Institute had occasion to experience.

Prof. Salam's many faceted contributions to science and to society will remain an inspiration for all to come.

67.21 Dr. Galileo Violini, Director, Comisión Europea, Universidad de El Salvador, San Salvador, November 27, 1996.

I have been in contact with Professor Salam for about thirty years, not only for my scientific activity, but mainly in connection with the creation and the development of a Center of Physics in Colombia, established very much along the model of ICTP. In this activity he has been for me a constant point of reference, with his ideals, experience and availability, to collaborate and support. Moreover, the Center was honored by having him as Chairman of its International Scientific Council for almost a decade.

67.22 Dr. Tchavdar Palev, Bulgarian Academy of Sciences, November 27, 1996.

Back in 1967, the first years of ICTP, he introduced and guided me into the amazing world of High Energy Physics. I owe a lot to him. ... Professor Salam did a lot for the scientific growth of our Department of High Energy Physics at the Institute of Nuclear Physics and Nuclear Energy of the Bulgarian Academy of Sciences.

67.23 Dr. D.A. Akveampong, Department of Mathematics, University of Ghana, November 28, 1996.

Prof. Abdus Salam's contributions to the promotion of advanced research in the basic sciences in Africa, in particular, will be with us forever.

67.24 Dr. Sing Lees, University of Malaya, November 29, 1996.

It was a visit of Prof. Abdus Salam to the Plasma Research Laboratory at the University of Malaya in January 1986 during our UNU Training Programme on Plasma and Laser Technology and the grant that he gave for follow-up equipment to the UNU Fellows that has played a key role in the formation of the AAAPT in 1988. It was in remembering what he saw on that visit that Prof. Abdus Salam had agreed to be the Patron of AAAPT. His ideals and ideas had inspired the actions and results of the AAAPT.■

68

Excerpts from Selected Obituary Articles on Dr. Abdus Salam (1926-1996)

68.1 "A Hero is Gone" by Dr. Pervez Hoodbhoy. *The Dawn* (Karachi), November 22, 1996.

With the death of Prof. Abdus Salam, the world has lost one of the mightiest intellectuals born on the subcontinent, and the most powerful and influential advocate of science for developing countries. To the world of physics he has left a legacy, known as the Unification Theory that is now a benchmark against which future progress in physics will be measured. To the countries of the Third World, he has left behind a unique institution in Italy, which invites and benefits over a thousand scientists each year.

I first saw Prof. Salam in 1972 when he came to Cambridge, Massachusetts, to give a talk at MIT. I was nearing the end of my Master's degree in physics, but I understood nothing of his lecture and just sat in awed wonder. From the critical appreciation of the audience, who included some of the most well-known physicists at MIT and Harvard, I was however able to infer that this was no ordinary seminar and Salam was considered no ordinary visitor.

It was many years later, and after having had to learn a great deal more of physics, that I was able to understand Salam's incredibly deep and beautiful work of physics which earned him the Nobel Prize in 1979. It is hard to describe something so sophisticated in simple words but an analogy might help. More than a century ago, James Clark Maxwell had showed that magnetism and electric forces were actually the same thing, an achievement which led to the discovery of radio waves and much else.

In 1968, Salam showed that electromagnetism and the so-called "weak forces", which lead to light and heat being emitted from the sun and stars, were also actually just different aspects of a more fundamental "electroweak" force. His discovery, and prediction of certain particles completely unknown at that time, sparked a wave of interest all over the world and billion-dollar experiments were set up to check the predictions.

Salam was an intimidating personality. I can remember that the first time I asked him a physics question was after I had received my doctorate in nuclear physics in 1978. "Go look it up in a book," was his curt reply. I felt thoroughly

chastened and small. It wasn't until 1984 that I approached him again. It was different this time, and we developed an understanding, which grew deeper and finer with each passing year. He asked me to co-author with him an article. I accepted instantly, feeling distinctly proud of the honor. [...]

Salam is gone. There is no Pakistani, or for that matter any scientist from any Muslim country, who even remotely approaches him in stature. The loss is irreparable. Let us mourn.

68.2 "Abdus Salam –The Human Side" by Dr. Mujahid Kamran, Professor of Physics, University of the Punjab, Lahore. *The News International* (Karachi), November 26, 1996.

From a very early age Salam, under the watchful eyes of his father, developed a love of reading. I once said to him that his father had left a deep mark on him to which he promptly responded, "Yes, you are correct."

He was not only brilliant but also had the gift of immense concentration. He was able to develop and retain this trait throughout his life. There are numerous instances, which illustrate this. I will mention only two, one from his childhood and one from his later years. The childhood incident has been narrated to me by his first cousin Col. G.M. Iqbal, who is also his brother-in-law. One day, his mother kept on calling him but there was no response. The worried family launched a search for him. Eventually, he was discovered inside the house hidden behind a stack of quilts reading a book quite oblivious of the hullabaloo that accompanied the search for him, Col. Iqbal further said that Salam used to find for himself suitable nooks and corners or other places in the house where he could concentrate on whatever he was reading.

The second incident is from the year 1992 when I last met him. At the time his illness, a rare disorder of the nervous system, had rendered it impossible for him to walk easily even with a stick. Adjoining his office was a room where he used to rest alone around lunch time. He asked me to walk him to that room. It was with quite a bit of difficulty that we managed to walk upto the door of his office when he spotted a recent research paper lying on the top of a stack of papers on a chest-high safe or rack. He stopped instantly and started looking at the paper. And then suddenly I felt that he was no longer with me. He was completely absorbed in it for several minutes and I could sense his immense powers of concentration. His illness, his difficulty in standing, seemed to have disappeared for those minutes and there was an air of such intense absorption about him that it appeared to me that he would not come out of it. Then he gradually came out of it and we walked to the next room silently.

Salam was gifted with an extraordinary memory. While he was a college student his class fellows were well aware of this gift of his. Prof. Dr. Waheed Qureshi, one of the foremost experts in Urdu language and literature, was his class fellow in B.A. at Government College, Lahore. Dr. Qureshi has confirmed

to me the following incident. One day, a group of class fellows including Salam walked through Anarkali Bazar. When they reached the other end, Dr. Waheed Qureshi tested Salam by asking him to recall the name boards on the shops on the right side. In the words of Dr. Qureshi, Salam was able to recall "about 90%" of the names. Dr. Qureshi remarked that what was remarkable was the fact that the question was not planned and Salam had not been mentally prepared in this regard before hand.

68.3 "Abdus Salam: A Torch of Light" by Dr. Zafar H. Zaidi, University of Karachi, at the Opening Ceremony of the 8th General Meeting of the Third World Academy of Sciences, Trieste, November 26, 1996.

The scientific accomplishments of Prof. Salam are universally acknowledged. Rather than recounting his academic accomplishments, in the limited time I have, I shall confine myself to certain aspects of his personality which have left an indelible mark in the hearts and minds of his compatriots. The foremost of these was his humility which stemmed out of the greatness of his mind and soul.

Pakistan, his motherland, is extremely proud of her illustrious son who strove for enlightenment all his life. He was up against massive hurdles raised by the forces of darkness and obscurantism, but his spirit remained undaunted. He worked tirelessly to convince the powers that be in the Third World countries that scientific progress was sine qua non for the spiritual and material well being of their people. His concern for scientific progress was universal; nonetheless science and its future in Pakistan claimed a special place in his heart.

As the world bids an eternal farewell to him, Pakistan bleeds and enfolds him in an eternal embrace.

I recall a similarity in Prof. Salam and another great man of the sub-continent, also a Nobel Laureate, Rabindranath Tagore, who was in search of the same truth, but in a different realm, that is, literature and arts. I would like to recite a couplet from Tagore's *Gitanjali*:

I dive down into the depth of the ocean of forms,

Hoping to gain the perfect pearl of the formless.

The two are now not with us, but the torch of light they carried will continue to light our path.

68.4 "A Man of Remarkable Vision". *The Times*, London, November 26, 1996.

Professor Abdus Salam, theoretical physicist and Nobel laureate, died on November 21, age 70. He was born on January 29, 1926.

The death of Abdus Salam leaves the world of theoretical physics without one of its most distinguished and respected members. Born in Jhang, Pakistan, he was soon to display the outstanding creative ability that was such a consistent feature of his professional career. Indeed, his first published scientific paper was produced at the early age of 17. Undergraduate and postgraduate degrees followed from Government College, Lahore, and from the University of Cambridge.

The focus of his research was quantum field theory, with particular emphasis on the long-term goal of finding a unified approach to the fundamental forces at work in the worlds of nuclear and sub-nuclear physics. In the 1960s Salam was closely involved with the attempts to construct a theoretically coherent account of the "strong" interactions that bind together the constituents of nuclei.

The mathematical technique on which he worked at that time provided the foundations of the developments that followed a sustained program of research culminating in his construction of a theory that unified the electric and magnetic forces with the "weak" nuclear force responsible for the radioactive decay of elementary particles. The dramatic confirmation of this theory by experiments at the European particle-accelerator facility CERN led to his sharing the 1979 Nobel prize for Physics with the American physicists, Sheldon Glashow and Steven Weinberg. This critical theoretical development became the central component of what became known as the "Standard Model" of the electromagnetic and nuclear forces.

The incorporation of the gravitational field into this unified picture is a notoriously difficult problem and it is no surprise that this is another area to which Salam turned his formidable attention. The solution of this particular issue remains elusive but, working with his long-term collaborator John Strathdee, Salam developed some of the main tools for handling the "superfields" that later became major ingredient in the development of the superstring theory currently one of the most promising approaches to the problem of adding gravity to the list of unified forces.

In addition to his brilliant intellectual gifts, Salam was a man of remarkable vision and outstanding energy who played a major role in developing science throughout the world. Of particular significance was his success in 1964 in persuading the Italian government and the UN to found a research institute for theoretical physics in Trieste, Italy, the prime mission of which was to provide a base for young scientists from the developing countries to carry out research with each other and with visitors from the West.

Salam was the director of the International Centre for Theoretical Physics from 1964 to 1993, and it is a striking tribute to his charismatic and energetic personality that the Center survived, and indeed, flourished notwithstanding the numerous political difficulties that inevitably accompany an international project of this kind. ... He was also deeply concerned about the proliferation of nuclear weapons and served on many high-level committees

involved in the promotion of international peace and collaboration and in the development of peaceful uses of atomic energy. ...

On a personal level, Salam was a striking man. Any young scientist who had the privilege of working closely with him invariably found it to be an exhilarating and character-forming experience. In addition to his great intellectual gifts, Salam had a genuine sense of humor, including that rarest of qualities of being able to laugh at himself. A warm twinkle would often accompany his more unorthodox suggestions as to how exactly the foundation of physics should be revolutionized.

68.5 "Professor Abdus Salam – Some Reminiscences" by Prof. Saeed A. Durrani, School of Physics and Space Research, University of Birmingham, UK, December 1996.

My earliest memory of Salam goes back to the early 1940s – perhaps to the summer of 1940 when we in the Punjab of undivided India suddenly heard of a young Muslim student from an obscure school in Jhang who had shattered the matriculation record of the University of the Punjab.

Soon thereafter a personal connection became known to me. I learnt that a grand-uncle of mine, Hakim Muhammad Hussain, was, in fact, the Principal of the Government Intermediate College at Jhang, where he had taken a great personal interest in Salam's education. ...

It was at Government College, Lahore, that I first sighted Salam. He was already a legendary figure, a lean, handsome, tallish young man, with a small brush moustache, who was rarely seen outside his classrooms or his hostel room. I, too, was resident of the New Hostel, where Salam resided as a boarder, and where there were stories abroad about the superhuman industriousness of Salam. ... Anyway, soon after my arrival, Salam left the Government College, Lahore, for Cambridge, trailing clouds of glory. Then, around 1951, Salam returned to the College as a lecturer. He was then teaching a course of Quantum Mechanics at the University, and was staying at the house of the Principal of Government College, Qazi Muhammad Aslam. I sometimes ran into Salam at the College swimming pool. I was at the time a student of the M.Sc. class in Physics, and used to attend his lectures. Salam was an informal man and very friendly to his students.

An important event during that time was an international conference organized by the Pakistan Association for the Advancement of Science at Lahore which was attended, among others, by several Nobel Laureates, including Sir G.P. Thomson and Professor A.V. Hill. During this meeting many of us realized in what high regard Salam was held by the top scientists of the world; this was very uplifting for young students of science in the country. After the conference, the participants were taken by train to visit Peshawar and the historic Khyber

Pass. During that train journey, I had the opportunity to have several discussions with Professor Salam.

I next saw Salam in Cambridge, where I had gone for my Ph.D. studies at the Cavendish Laboratory on an Open Research Studentship in 1953. Salam arrived in Cambridge in 1954 as a Fellow and lecturer at St. John's College. I again attended his lectures (and those of P.A.M. Dirac) at the Department of Mathematics, University of Cambridge. I was struck by the mastery of both of these lecturers of their abstruse subject: Theory of Quantum Mechanics. But Salam also used to attend the meetings of societies such as the Majlis (which embraced students from the Indian sub-continent and concerned itself with their cultural and social activities.) [...]

After my Ph.D., it was Salam that I turned for advice as to the next step in my career. He suggested that I join the Atomic Energy Commission of Pakistan, it being the only scientifically active organization in the country. He offered to introduce me to Dr. I.H. Usmani, the brilliant Chairman of that Commission, who was a personal friend of Salam and always stayed with Salam at his Putney house in London whenever he was visiting England. This Salam did when Dr. Usmani next came to England, and so I met Usmani in Oxford. He said that working on hyperons was of no interest for Pakistan, and suggested that I change my field and specialize in reactor physics. This I did, and spent the next three years working with the UK Atomic Energy Authority at Harwell and Winfrith. I eventually joined the Commission in 1963, and was appointed Director of the Atomic Energy Centre at Lahore. Salam was a frequent visitor to that Centre in his capacity as Chief Scientific Advisor to the President of Pakistan. [...]

In 1967, I joined the faculty of the University of Birmingham, in the Department of Physics. And in 1979, when Salam won his Nobel Prize, I wrote to congratulate him. In his reply he wrote: "I am sorry your grand-uncle is not alive anymore – for he would have been proud of me today."

My next substantive interaction with Salam was in 1991 in Trieste, where I had gone as a faculty lecturer in a Radon workshop at the ICTP. Salam invited me to lunch and then a chat in his office early one morning. There he explained to me his concept of the Commission on Science and Technology in the South (COMSATS), which would be composed of heads of states or governments of the Third World countries of the globe, so as to exercise at the very highest level, the will for a revolution in science and high technology – which he had been pushing for several years as President of the Third World Academy of Sciences. During that November 1991 encounter, Salam was bemoaning the lack of progress in holding the foundation meeting of COMSATS in Pakistan – the country he dearly wanted to host the first meeting. He said [Prime Minister] Benazir Bhutto had agreed to join the Commission and hold the foundation meetings here – but her Government had fallen before she could do so. The new

Government, headed by Nawaz Sharif, had, he said, been dragging its feet. On the spur of the moment I offered to do what I could to help his cause – since I happened to be going to Pakistan in a month's time for a science conference. I asked him to give me a letter addressed to the President of Pakistan, with a copy to the Prime Minister. I also proposed to him that, by way of inducement, he should offer to locate the headquarters of COMSATS in the country that hosted the foundation meeting. Salam readily agreed to both my suggestions.

Armed with Salam's letters, I first called on the President of Pakistan, Mr. Ghulam Ishaq Khan, in January 1992. The President proved a hard nut to crack, but eventually he gave his blessing to the proposal, and asked me to see the Prime Minister, who was the proper authority in the matter. The Prime Minister was then away, but I finally caught up with him at the Economic Summit at Davos in Switzerland on February 1, 1992. Fortunately, I was able to persuade Mr. Nawaz Sharif that the foundation meeting of COMSATS be held in Pakistan – and even agree to a provisional date, February 1993 in Lahore. The Prime Minister ordered a provision of US\$2 million to be made in the next budget for the conference, likely to be attended by up to fifty heads of state/government. I rang Salam in Oxford, from Davos, with the good news; he was very pleased with the outcome and asked me to thank Mr. Nawaz Sharif and invite him to visit ICTP whenever he had a chance.

In June 1992, when the Prime Minister of Pakistan was passing through London on his way back from the Earth Summit in Rio de Janeiro, I drove Salam from Oxford to see Mr. Nawaz Sharif at the Dorchester Hotel in London. Mr. Sharif was visibly distressed to see Salam in such a poor state of health. He said to Salam: "Sir, because of you, there is much honor to Pakistan. And that, in turn, has brought honor to us. Please give us any orders, and we shall be happy to carry them out; and if there is anything that we can do to alleviate your health problems, please do not hesitate to let me know personally." It was all very touching, and showed in what high regard Salam was held by the leaders of Pakistan. The final decision on dates for the COMSATS foundation meeting was, however, deferred to the TWAS General Conference in Kuwait, to be held in November 1992. But once again, the Government of Pakistan (this time Mr. Nawaz Sharif's) fell before the meeting could be held.

We had to start all over again. Benazir Bhutto was once again in power, and I obtained a new letter from Salam, addressed to her, during the TWAS 10th Anniversary Celebrations in November 1993, and fortunately she agreed to honor her earlier pledge. She said Pakistan greatly needed Professor Salam's help and guidance, and on hearing in what poor health he was, she immediately sent him a personal get-well message and ordered a bouquet to be delivered to him at his London hospital.

The Foundation Meeting of COMSATS duly took place in Islamabad from 4 to 5 October 1994, with great pomp and ceremony, and the permanent headquarters of the Commission was located in Islamabad. But alas the author of all that grand plan was too ill to attend the meeting where his long-cherished

dream was coming true. I had actually foreseen that eventuality, and had formally proposed to both TWAS and ICTP that a portrait of Salam be painted for the occasion of the COMSATS meeting. I asked the world-renowned Pakistani portraitist Mr. Gulgee (who had done portraits of DeGaulle, the Shah of Iran, and Allama Iqbal) to make a special portrait of Salam – who was too ill to sit for a proper portrait. These sketches were then displayed at the COMSATS Foundation Meeting. So, if Salam was not able to be physically present at this historical meeting, at least his portrait sketch was there to savor the occasion. The selected sketch out of the series executed by Gulgee was shipped by me to Trieste from Islamabad in early 1995 – and it now hangs in the Galileo Galilei Guest House of the International Centre for Theoretical Physics.

I saw very little of Salam after the September 1994 portrait-making meeting until his death in November 1996, although I did speak to him over the telephone once or twice – when all I could hear was some whispers in his native Punjabi language. At the request of his wife, Louise, I translated for her into English some of the ghazals of the great Urdu poet Ghalib (1797-1869), whose tapes, she said, Salam enjoyed listening to, finding much solace in Ghalib's poetry. I sent to Professor Salam a cassette of a selection of the Urdu and Persian poetry of the poet-philosopher of the East, Muhammad Iqbal (1877-1938), which the Iqbal Academy (UK) – of which I am the Chairman – had produced in 1992. Salam was very knowledgeable about Urdu and Persian poetry, and Mrs. Salam said that he very much appreciated the tapes.

So, these are some of the reminiscences of the great man, Salam, whom I consider to be a scientific genius, on a par with Einstein, Dirac and Heisenberg. In the view of many of us, Salam deserved a second Nobel Prize – this time the Peace Prize for his life-long service to the development of science in the Third World. The ICTP and TWAS are two of his brain-children that will continue to glorify his name and his dedicated endeavors for science and for the Third World.

In the words of the 14th century Persian poet Hafiz:

He whose heart has been animated by love, never dies

His immortality leaves a lasting imprint on the Chronicles of Time.

Salam's name is, verily, so imprinted.

68.6 "Farewell to Abdus Salam" by Julius Nyerere, *South Letter*, The South Centre, No. 27, December 1996.

Professor Muhammad Abdus Salam, member of the South Commission from Pakistan, died on 21st November 1996, at the age of seventy. Nobel Prize winner in Theoretical Physics, he was internationally famous for his intellectual achievements but, especially in the South, also as the founder and leader of the

Third World Academy of Sciences and a leading champion of the role of Science and Technology in development. Being on the South Commission broadened but did not add much to his fame; it did make a lot of difference to the Report of the Commission.

Abdus Salam was committed to two things: to Science; and to the development of the countries of the South. From the first meeting of the Commission, the other members learned that, to Professor Salam, the development of South countries depended upon their giving first priority to Science. Whatever aspect of development was under discussion, Abdus Salam brought it round to Science and Technology.

The emphasis given to Science and Technology in the South Commission's Report – *The Challenge to the South* – is thus entirely due to Abdus Salam. That the subject was completely integrated into the Report, rather than being isolated in one or two chapters, can be attributed in part also to his work in tandem with another Commission member, Augustin Papic.

Despite his deteriorating health from the end of 1988, Abdus Salam was assiduous in attending South Commission meetings, including that called in 1992 – two years after the Report was published. That same year, encouraged by his success on the South Commission, but wanting still more emphasis, he expanded on the facts, figures, and arguments in a publication entitled *Science and Technology: Challenge for the South*. And later still, it was as a result of his initiative that the *Profiles of Institutions for Scientific Exchange and Training in the South* was prepared by the Third World Network of Scientific Organizations, and published jointly by the South Centre.

His single-mindedness did not always make Abdus Salam an easy colleague. But everyone on the Commission liked him – as well as respected him. For he was a man of great simplicity of character, demanding nothing for himself except a chance to serve what he believed in. The South Centre is among many organizations dedicated to the development of the countries of the South which are poorer for his passing.

68.7 “Abdus Salam (1926-96)” by Dr. Seif Randjbar-Daemi, International Centre for Theoretical Physics, Trieste, Italy. [“Obituary” in *Nature*, Vol. 384, December 12, 1996, p. 520.]

Among the great intellectual achievements of this century is the theory of elementary particles that has come to be known as the Standard Model. It represents the cumulative effort of many profound and imaginative thinkers whose common motivation was to find some glimmer of understanding as to what the physical world is made of and how it works. This kind of endeavor is very much in the European tradition, and much of the work was carried out in the wealthy universities of Europe and North America. But among the creators of this intellectual system there are some from other, less wealthy parts of the world. One such is Abdus Salam, who died on November 21. Salam made a

major contribution to the creation of the Standard Model. For this work he shared the Nobel prize with Steven Weinberg and Sheldon Glashow in 1979.

The Standard Model is the best existing mathematical description of the physical phenomena that take place on subnuclear scales. Its predictions have been confirmed to a high degree of accuracy. The main element in the construction of this model is a type of field theory known as Yang-Mills theory. In the 1950s, Salam, together with J.C. Ward, was one of the first to appreciate the significance of the Yang-Mills theory in the description of weak nuclear forces.

Then in 1962 an important theorem, due originally to Goldstone, was proved by Salam, Weinberg and Goldstone. Its extension and application to models of the Yang-Mills type by Higgs, Kibble and others led to an understanding of how the Yang-Mills vector particles can become massive. This was the last ingredient needed for the construction of a unified theory of weak and electromagnetic interactions, and the electroweak theory of Weinberg and Salam soon followed. [...]

A guiding principle during his entire active life was that of symmetry. During the early 1960s, together with Gell-Mann and others, he emphasized the group-theoretical classification of hadrons. Salam's contribution, together with John Strathdee, to a rather abstract form of symmetry known as supersymmetry is well known. In 1974 and 1975, they invented a mathematical framework of supersymmetry known as superspace. As an aside, it may not be well known, even among the experts, that several terms in common use by physicists, such as electroweak theory, astroparticle physics and supersymmetry, were invented by Abdus Salam.

Also in the mid-1970s, Salam and Robert Delbourgo were the first to formulate a possible violation of the equivalence principle in general relativity, due to the quantum effects of chiral fermions. This work influenced the development of gravitational instantons by Stephen Hawking and others. Salam and Jogesh Pati were among the first group of theoreticians to propose the idea of a grand unified theory encompassing electroweak and the strong nuclear forces, and that in such models the proton may be unstable. [...]

Even if he had not been such a creative and influential scientist, Salam would have been remembered for the creation of the ICTP and for his charismatic leadership. The Centre has had a significant impact on the development of science in that large part of the world where, perhaps due to social and political conditions, the basic sciences are almost completely ignored. The ICTP is, and has been, a meeting point for physicists of all cultures and religions. For example, during the Cold War it was one of the few institutions where scientists from the Soviet bloc countries could meet and collaborate with their Western colleagues.

The ICTP has overcome many seemingly insurmountable difficulties to become as well established as it is now. Only a person of Salam's moral and

intellectual power, fired by a dedication to the well-being of the neglected part of humanity, could have made this enterprise survive. His relentless efforts on the political front are legendary. He talked with some of the most important political leaders of his time, from John F. Kennedy and Zhou Enlai to François Mitterrand and Margaret Thatcher. [...]

During his last years of life Salam suffered from neurological disorder, progressive supranuclear palsy. This was perhaps the only significant battle, among so many, that he fought but did not win. He bore the illness with grace and tranquility. He accepted with equal humility the great gifts that enabled him to act so effectively in science and for the Third World, and to face the vicissitudes of illness.

It was difficult not to be impressed by the forceful but deeply humane personality of Abdus Salam. He had a genuine respect for others and a very intelligent sense of humor. What he generously gave to others were his time and inspiration, perhaps the most valuable gifts that such a singular person could offer to his fellow human beings.

68.8 "A Tribute to Abdus Salam" by Dr. M.J. Duff, Center for Theoretical Physics, Texas A&M University, USA. An after-dinner talk at the "Workshop on Frontiers in Field Theory, Quantum Gravity and String Theory", Puri, India, December 12, 1996.

The death earlier this month of Abdus Salam was a great loss not only to his family and to the physics community, it was a loss to all mankind. For he was not only one of the finest physicists of the twentieth century, having unified two of the four fundamental forces in Nature, but he also dedicated his life to the betterment of science and education in the Third World and to the cause of world peace. Although he won the Nobel Prize for physics, a Nobel Peace Prize would have been entirely appropriate. [...]

Undoubtedly, the great influence on Salam at the early stages of his career was his mentor at St. John's, the great Paul Dirac, who remained Salam's hero throughout his life both as a great physicist and as a man who was largely disinterested in material wealth. (Salam himself never craved material riches, and was known to have paid for poor Third World students and postdocs out of his own pocket.) ... I was fortunate enough to be his Ph.D. student from 1969 to 1972. [...]

Among Salam's earlier achievements was the role played by renormalization in quantum field theory when, in particular, he amazed his Cambridge contemporaries with the resolution of the notoriously thorny problem of overlapping divergences. His brilliance then burst on the scene once more when he proposed the famous hypothesis that *All neutrinos are left-handed*, a

hypothesis which inevitably called for a violation of parity in the weak interactions. He was always fond of recalling his visit to the formidable Wolfgang Pauli where he submitted (or should I say "humbly" submitted) his two-component neutrino idea. Pauli sent him packing unceremoniously with the jibe that this young man does not realize the sanctity of parity! So Salam delayed publication until after Lee and Yang had conferred the mantle of respectability on parity violation. That taught Salam a valuable lesson and he would constantly advise his students never to listen to grand old men. (I hope this student, at least, has lived up to that advice!) It also taught him to adopt a policy of publish or perish, and his scientific output was prodigious with over three hundred publications.

Of course, the work that won him the 1979 Nobel Prize that he shared with Glashow and Weinberg was for the electroweak unification which combined several of his abiding interests: renormalizability, non-abelian gauge theories and chirality. His earlier work in 1960 with Goldstone and Weinberg on spontaneous symmetry breaking and his work with John Ward in the mid 1960s on the weak interactions was no doubt also influential. One of my greatest regrets is that as a student in the Theory Group at Imperial from 1969 to 1972, a group that included not only Abdus Salam but also Tom Kibble, no one suggested that weak interaction physics would be an interesting topic of research. In fact, I did not learn about spontaneous symmetry breaking until after I got my Ph.D. The reason, of course, is that neither Weinberg nor Salam (nor anybody else) fully realized the importance of their model until 't Hooft proved its renormalizability in 1972 and until the discovery of neutral currents at CERN. Indeed, the Nobel Committee was uncharacteristically prescient in awarding the Prize to Glashow, Weinberg and Salam in 1979 because the W and Z bosons were not discovered experimentally at CERN until 1982. Together with Pati, Salam went on to propose that the strong nuclear force might also be included in this unification. Among the predictions of this Grand Unification Theory are magnetic monopoles and proton decay: phenomena, which are still under intense theoretical and experimental investigation. More recently, it was Salam, together with his lifelong collaborator John Strathdee who first proposed the idea of superspace, a space with both commuting and anticommuting coordinates, which underlies all of present day research on supersymmetry.

However, it is to Abdus Salam that I owe a tremendous debt as the man who first kindled my interest in the Quantum Theory of Gravity: a subject which at the time was pursued only by mad dogs and Englishmen. (My thesis title: *Problems in the Classical and Quantum Theories of Gravitation* was greeted with hoots of derision when I announced it at the Cargese Summer School en route to my first postdoc in Trieste. The work originated with a bet between Abdus Salam and Hermann Bondi about whether you could generate the Schwarzschild solution using Feynman diagrams. You can (and I did – but I never found out if Bondi ever paid up). It was inevitable that Salam would not rest until the fourth and most enigmatic force of gravity was unified with the

other three. Such a unification was always Einstein's dream and it remains the most challenging task of modern theoretical physics and one which attracts the most able and active researchers, such as those here tonight.

I should mention that being a student of someone so bursting with new ideas as Salam was something of a mixed blessing: he would allocate a research problem and then disappear on his travels for weeks at a time (consequently, it was to Chris Isham that I would turn for practical help with my Ph.D. thesis). On his return he would ask what you were working on. When you began to explain your meager progress he would usually say, "No, no, no. That's all old hat. What you should be working on is this," and he would then allocate a completely new problem! After a while, we students began to wise up and would try to avoid him until we had achieved something positive. Of course the one place that could not be avoided was the men's room. So if you were unlucky, that was frequently the location of receiving your new orders.

I think it was Hans Bethe who said that there are two kinds of genius. The first group (to which I would say Steven Weinberg, for example, belongs) produce results of such devastating logic and clarity that they leave you feeling that you could have done that too (if only you were smart enough). The second kind are the "magicians" whose sources of inspiration are completely baffling. Salam, I believe, belonged to this magic circle and there was always an element of eastern mysticism in his ideas that left you wondering how to fathom his genius. [...]

Let us recall just one example of a crazy Salam idea. In that period 1969-72, one of the hottest topics was the Veneziano Model and I distinctly remember Salam remarking on the apparent similarity between the mass and angular momentum relation of a Regge trajectory and that of an extreme black hole. Nowadays, of course, string theorists will juxtapose black holes and Regge slopes without batting an eyelid but to suggest that black holes could behave as elementary particles back in the late 1960s was considered preposterous by minds lesser than Salam's. (A comparison of the gyromagnetic ratios of spinning black holes and elementary string states will, in fact, be the topic of my technical talk at this conference, so in this respect Salam was twenty-five years ahead of his time!) As an interesting historical footnote let us recall that at the time Salam had to change the gravitational constant to match the hadronic scale, an idea which spawned his strong gravity; today the fashion is the reverse and we change the Regge slope to match the Planck scale!

Theoretical physicists are, by and large, an honest bunch: occasions when scientific facts are actually deliberately falsified are almost unheard of. Nevertheless, we are still human and consequently want to present our results in the best possible light when writing them up for publication. I recall a young student approaching Abdus Salam for advice on this ethical dilemma: "Professor Salam, these calculations confirm most of the arguments I have been making so

far. Unfortunately, there are also these other calculations which do not quite seem to fit the picture. Should I also draw the reader's attention to these at the risk of spoiling the effect or should I wait? After all, they will probably turn out to be irrelevant." In a response, which should be immortalized in *The Oxford Dictionary of Quotations*, Salam replied: "When all else fails, you can always tell the truth."

68.9 "Many Salaams to Dr. Salam" by Dr. Aftab Ahmed. *The Dawn*, Karachi, December 13, 1996.

Professor Dr. Abdus Salam's passing away has been widely mourned by most thinking people, and especially by the scientific community of Pakistan. His services to the cause of science, his achievements as a great scientist and the only Nobel Laureate from Pakistan have been duly eulogized with reverence.

I write this to remember him as a friend. This takes me to the days when we were both students at the Government College, Lahore, in the mid-forties. Actually, we came to know each other fairly well through some common friends at the time when I was seeking admission to the M.A. English class, and Salam was still in the process of deciding whether he should study English or Mathematics. And there hangs a tale.

Those were the days of Hindu-Muslim rivalry in all spheres of life including the academic. Salam had stood first in the Punjab university's B.A. exam, with English Honors and had broken all previous records. He had become a legendary figure among the students. Prof. Sirajuddin of the English Department wanted Salam to join the M.A. English course because he thought he would easily secure a first class first – a laurel which had not been won by a Muslim student in a long time. Salam toyed with the idea but, in spite of Prof. Sirajuddin's persuasion to the contrary, he finally decided to join the M.A. course in Mathematics. His decision at that moment in time did indeed set him on the road to glory that finally led to his achieving the most prestigious prize in his chosen field. [...]

The most memorable meeting I had with Salam was in his office at the Imperial College, London, in October 1989. He had been affected by his ailment but was still much the same Salam one knew; tall and burly, with a hearty laugh and a warm and firm handshake. He was able to talk in his usual manner, and could also walk around a little. In fact, he led me to the College cafeteria, taking an elevator and passing through a maze of corridors. I remember when we had selected a table and were about to make a move to get our coffee, the girl at the counter motioned us to keep sitting. She was going to bring our coffee to the table. This was out of respect for Prof. Salam.

While we were waiting, I looked around and spotted his picture on a wall along with other great scientists of the world. Meanwhile, some young scholars from the College came to Salam, with their autograph books. He obliged them all with a smile and a handshake.

Soon after, he started talking to me about the old days at Lahore, and how he missed his country and his people. I could see that he was getting a bit excited. I tried to change the subject by referring to his achievements during his stay abroad, the high esteem in which he was held and pointed to his picture on the wall. He got even more excited and said: "You say this because you can't feel the way I do. You live in your country and among your people!" As soon as Salam had uttered these words, his eyes became wet and tears started rolling down his face. I just held his hand and did not know what to say.

But the Salam I met in his Oxford home in July, 1994, was not the same Salam. I was meeting him after nearly five years. As I entered his sitting room, I saw his shrunken figure slumped into a sofa chair with his sweater and trousers hanging around him loosely. No more was the hearty laugh, just a faint smile, and no more the firm handshake. As I sat down, he just fixed his gaze on me and kept listening to what I was saying. He murmured a few words but could not converse with me. His ailment had taken its toll. Only his eyes had some of the old shine.

Just before leaving Oxford when I went to say goodbye to Salam, his son Umar asked me to write something in the visitors' book. Keeping in mind Salam's curiosity about the nature of the Universe as a scientist, and his interest in Ghalib which he had evinced when I presented my book on the poet to him during our meeting in October 1989, I added, to the few words in English, a couplet from Ghalib.³ Salam looked at what I had written, gave me a smile with a nod and extended his hand to me – a gesture I will never forget.

68.10 "Physics with a Purpose" by Ehsan Masood, *Nature*, December 27, 1996.

Muhammad Abdus Salam, the Nobel-prize winning scientist, who died last week, age 70, was in London when the phone rang at noon on an autumn day in 1979. The call was long-distance from Stockholm, headquarters of the Alfred Nobel Foundation. Salam, the devoutly religious son of a school teacher from a

³ Ghalib's Urdu couplet was not printed in the English text. It could have been:

Ranj se khoogar hua insaan to mit jaata hai ranj
Mushkilayn itni pareen mujh par kih aasaan ho gaeen
 (Once one gets to know sorrow so well, it loses its pain,
 I have borne so many hardships, they are no longer a burden!)

village in Punjab had won the Nobel Prize for Physics. He remains the first and only Pakistani to have been given science's highest order.

Salam's instinctive reaction, according to his biographer, the Indian science writer Jagjit Singh, was to jump into his car and drive to his local mosque where he took off his shoes and knelt in prayer. Salam's joy turned to near ecstasy when he learnt that he had been nominated by Paul Dirac, the leading physicist of this century, who was also an atheist. "What impressed Salam most was that the atheist Dirac had become an instrument in executing Allah's will."

Salam's next action was to use his new-found recognition to secure a four-fold increase in funding for the ICTP, a center for providing modern research facilities for Third World scientists. The facility was founded by Salam in 1964 and is based on the shores of the Adriatic in Italy, near the border with what was Yugoslavia. Salam was later given a presidential reception in his native Pakistan, before embarking on a tour of the Third World countries giving lectures on science, education, and the eradication of poverty, the three subjects (apart from physics) for which Salam's passion ran very deep.

Salam's major scientific achievement was to take the first step towards an idea that his scientific peers still dream about – the unification of the four fundamental forces of nature: gravity, the strong force between particles in the atom, the weak force that causes radioactive decay, and electromagnetism. Salam shared the Nobel Prize with Steven Weinberg and Sheldon Glashow for unifying the weak force with electromagnetism. John Hassard, a colleague at Imperial College in London, where Salam was a professor of theoretical physics since 1957, ranks him in the "top ten, if not top five, physicists of this century".

But just as the organizers of the Miss World annual pageant feel obliged to delve into social causes under the banner "beauty with a purpose", Salam felt he could not restrict his time and energy to just theoretical physics. He felt compelled to use his fame to champion a plethora of Third World causes. This was "physics with a purpose".

Like his Nobel-winning colleague Stephen Weinberg, Salam too dreamed of a final theory unifying the forces of nature, but he had an additional wish: that the developing world would one day catch up with the West. A part of him wished that no one should have to experience life without electricity, running water, medical care, proper roads and decent transport, as he had to while growing up in Punjab during the inter-war years. Another part of him pined for a return to the "glorious years" of Islamic civilization when sciences flourished in the Muslim world.

In this Salam was almost messianic. Like the sages of Judaism, Christianity and Islam, whose lives he tried to emulate, Salam felt duty-bound to complete his mission. He was tremendously impatient and experienced much frustration when politicians failed to share his zeal and enthusiasm every time he presented them with another of his schemes for science, technology, or development.

Salam was particularly passionate about his native Pakistan, and desperately wanted to “make a difference” to the lives of ordinary people. Yet in Pakistan he remains a deeply controversial figure, and his passion was not reciprocated. Some cannot comprehend why he never made Pakistan his home. Others cast a critical eye over his record of achievement as the President’s chief scientific advisor for fourteen years until 1974.

68.11 “Abdus Salam (1926-96)” by Dr. Tom Kibble and Dr. Chris Isham, Professors of Theoretical Physics, Imperial College of Science, Technology and Medicine, London. [First published in *Physics World*, January 1997, p. 54.]

The great excitement at this time [Salam’s student days at Cambridge] was the development of renormalization theory – a way of circumventing the infinities that had plagued quantum electrodynamics (QED) since its inception. The main work in this area was being done by Julian Schwinger, Sin-itiro Tomonaga, Richard Feynman and Freeman Dyson. [Paul] Matthews had been using Dyson’s methods to extend renormalization theory to the meson theories that were then thought to describe the strong nuclear forces. He suggested that Salam should try to fill in a gap in Dyson’s proof of renormalizability – the treatment of “overlapping divergences” and was astonished when Salam returned within days with a complete solution. Salam became Matthews’ student and spent a year with him in the Institute for Advanced Study at Princeton in the US. Thus began their close and lasting friendship and collaboration. [...]

Working directly with Salam was quite an experience, and not everyone who took up the challenge survived the pressure for long. Salam thought nothing of working for fifteen hours a day and he took it for granted that his young collaborators would be similarly dedicated. Thus it was not unusual to be woken at around five in the morning – Salam was a notorious early riser – with a lengthy phone call in which he would reveal his latest ideas for the piece of work in progress. These would usually involve many lengthy equations that he would dictate at speed using his own personal shorthand for the superscripts, subscripts and other such mathematical niceties with which the equations were invariably adorned.

Collaborating with Salam was, however, far from being just a matter of hard grind. He had a charismatic personality and generated great loyalty from those who worked with him closely, whether they were fellow scientists or the secretaries at the ICTP charged with keeping his affairs in some degree of order. Salam was a complex man and people who encountered him in a variety of circumstances experienced him in different ways. His young collaborators invariably thought of him with respect and affection, and there is a fund of

"Salam stories" waiting to be told that speak of his good humor and warm personality. [...]

68.12 Excerpts from "Abdus Salam" by Dr. Jogesh C. Pati, University of Maryland, College Park, Maryland, USA. ["Obituaries: Abdus Salam" in *Physics Today*, August 1997, pp. 74-75.]

My personal collaboration with Salam started in the summer of 1972 and remained intense for over ten years. Together, we introduced the idea of an underlying unity of quarks and leptons and, simultaneously, of their weak, electromagnetic and strong gauge forces. Believing in $SU(4)$ color symmetry for quark-lepton unification and seeking a compelling reason for quantization of electric charge, we introduced the concept of left-right symmetry. This in turn led us to predict the existence of right-handed neutrinos accompanying the observed left-handed ones – a prediction that now plays a role in proposed solutions to the solar neutrino puzzle and in theories of dark matter.

In 1973, despite the skepticism of the physics community at the time, Salam and I noted that a gauge unification of quarks and leptons would inevitably lead to nonconservation of baryon and lepton numbers and thereby naturally to an unstable proton. These ideas have matured and evolved considerably. Salam had hoped to see a more final chapter of this story of unification in his lifetime. We were both encouraged, however, to see that the search for proton decay was continuing with the recent completion of the Superkamiokande detector in Japan.

During our collaboration, Salam always reacted to our occasional disagreements with a good-natured spirit. If he were greatly excited about an idea that I did not like, he would impatiently ask, "My dear sir, what do you want? Blood?" I would reply, "No, Professor Salam. I would like something better." Whether I was right or wrong, he never took it ill. [...]

Thanks to Salam's tireless efforts, the ICTP has emerged as one of the finest research-cum-training institutions in the world, not only producing high-quality science but also providing opportunities for scientists from developing and developed nations to interact regularly through annual workshops and summer schools. In its thirty-three years, the ICTP has hosted some 60,000 visits by experimental and theoretical research physicists, about half of whom are from the developing countries. [...]

Salam dreamed of creating twenty international centers like the ICTP, spread throughout the world and emphasizing different areas of science and technology. He appealed vigorously to the developed as well as many developing countries and to the World Bank for funds to create the centers. Meanwhile, Salam also dreamed of creating a "World University", which would be funded internationally and would be linked for its functioning to a consortium of universities worldwide.

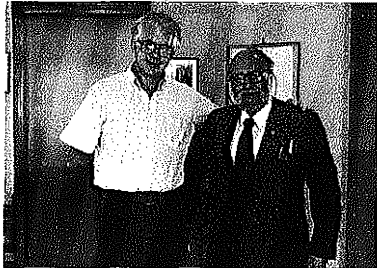
Salam's efforts in these directions in the last eight years of his life were unfortunately severely hampered by a crippling neurological illness, attributed to a variant of Parkinson's disease. Thanks to his own initiative and that of several others, he nevertheless succeeded in creating the International Centre for Genetic Engineering and Biotechnology, with components in Trieste and Delhi, and the International Centre for Science and High Technology in Trieste.

Salam will surely be remembered as one of the greatest scientists of the 20th century and as a humanitarian who devoted much of his life to uplifting the status of science and technology in the third world. Salam may have been somewhat ahead of his time in dreaming of twenty international centers and a world university. It remains for the present generation of scientists and world leaders to fulfill his dream.

68.13 "Memories of Abdus Salam" by Dr. Sheldon L. Glashow, Nobel Laureate, Professor of Physics, Harvard University.⁴

I consider it a great pride to pay salute to the memory of a great scientist and humanitarian. My encounters with Abdus Salam were all too few and far between, but they extended over five decades. Our relationship, most appropriately, was a weak interaction with a very long lifetime. I miss Abdus Salam, and will always remember the scent of attar of roses that he was never without.

Our scientific interests often overlapped, sometimes somewhat uncomfortably, but we were always fast friends and mutually supportive



73. With Sheldon Glashow, 1986

colleagues in science. We coulda, shoulda and woulda, but I regret that Abdus and I never actually collaborated in print or by correspondence. I visited him only twice in London, twice again in Trieste, and otherwise saw him only at conferences and summer schools, or as a fellow member of the CERN Science Policy Committee. In addition, we met four times in Stockholm: at a remarkable conference just prior to our Nobel Awards; at our own very special occasion; once again when Carlo Rubbia and Simon Van der Meer (and CERN itself) were honored for the discovery of all three intermediate vector bosons, thereby justifying our own awards; and lastly, at a grand reunion in Stockholm not so long ago.

Although our face-to-face meeting could be counted on our fingers and toes, Abdus and I knew each other very well. My colleagues will undoubtedly recall Abdus as an inspirational mentor, as a world-renowned scientist, as the creator of

⁴ Presented at the Special Colloquium in Memory of Professor Abdus Salam at the European Organization for Nuclear Research (CERN), Switzerland, September 23, 1997

the International Centre for Theoretical Physics and its guiding spirit for thirty years, and as a champion of science and technology in the Third World. I would take this opportunity to tell you of a few personal and memorable moments I have enjoyed with one of the kindest, gentlest and most gracious people I have ever known.

In 1955, soon after I began my career in physics as Julian Schwinger's graduate student, I heard tales of a marvelous and mysterious man of the East from Wally and Celia Gilbert, who had just moved from Cambridge, England to Cambridge, Massachusetts. Wally was a Junior Fellow at Harvard as he completed the doctoral research program he had begun under Salam's guidance. Wally got his degree with Abdus, became a promising professor of formal theoretical physics at Harvard, and then turned his attention to hands-on molecular biology. A quarter of a century later, Salam was both proud and delighted when the student won a Nobel Prize just one year after his teacher.

My first direct interaction with Abdus was a touch embarrassing: to me, not to him. I was continuing my thesis research on the intermediate vector boson hypothesis as an NSF fellow at the Institute for Teoretisk Fysik in Copenhagen, now the Niels Bohr Institute. My other high-school chum, Gary Feinberg (besides Steven Weinberg), had recently published an important paper. At least, it was important to me! He argued as follows: If the weak force were mediated by a vector boson, and if the muon and electron neutrinos were one and the same, then the process muon decaying into electron and photon would be induced by radiative corrections and would proceed at an empirically unacceptable rate. Of course, Schwinger had already convinced me that muon and electron neutrinos could not possibly be the same, so I wasn't particularly worried. It was another aspect of Feinberg's calculation that fascinated me.

Gary had to use a cutoff to get a finite result – unless the vector boson had a particularly anomalous magnetic moment corresponding to gyromagnetic ratio two. For this value and only for this value, the divergence cancels and the result is manifestly finite. And, this was precisely the anomalous moment predicted by a Yang-Mills gauge theory! If one divergence cancelled in a gauge theory, maybe all of them did. So I concocted and published a spurious argument alleging that softly-broken Yang-Mills theories are renormalizable. Following the Gilberts' advice to meet their beloved guru, I accepted Salam's invitation to present my results at Imperial College. After my talk, which seemed well received, Salam brought me to his home for a wonderful dinner his wife had prepared. When I returned to Copenhagen, two preprints awaited me; one by Salam, and the other by Kamefuchi – both of them pointing out my silly error. Years later, Abdus confided to me that this was the reason he had not read my next (and somewhat better) electroweak paper. It was a good excuse!

In 1962, Feza Gursey organized a marvelous Turkish summer school at Roberts College by the beautiful Bosphorus. Salam and I were among the invited speakers. It was an exciting time in particle physics. A few months earlier, the higher symmetry sweepstakes had been won by the scheme of strong interactions devised by Yuval Ne'eman (another of Salam's remarkable students), and independently, by Murray Gell-Mann. It had been a strong field: The also-rans included Schwinger's global symmetry, Behrand's G_2 , Tiomn's $SO(7)$, and Salam and Ward's symplectic hedge bet. $SU(3)$ a la Sakata (later pursued by Salam and Ward) was somewhat closer to the mark. My talks explicated the intricacies of the eightfold way [the old name for flavor $SU(3)$], including those I had just worked out with Sidney Coleman.

Abdus used his lectures to describe his just-completed exploration of broken symmetry with Jeffrey Goldstone and Weinberg. Salam seemed absolutely convinced of the central role played by spontaneous symmetry breaking in particle physics, although he could not yet handle the seemingly unavoidable Goldstone boson, which he would later describe as "a snake in the grass ready to strike". Our friendship blossomed as we wandered about the scenic splendors and seedier side streets of downtown Istanbul, dreaming together of an eventual and obligatory synthesis of weak and electromagnetic forces, and of the next wondrously imaginative Turkish dinner. Of course, we realized all too well that our old ideas (his several papers with John Ward and mine at Copenhagen) were likely to be consigned to the dustbin of history.

Two years later, Higgs (as well as Brout and Englert, and somewhat later, Tom Kibble and his collaborators) surprised the world with their discovery of the gauged version of spontaneous symmetry breaking. Like Saint Patrick in Ireland, they had driven Salam's snakes from the land of broken symmetry. Quite independently, Abdus and Steve each seized the idea and formulated the electroweak theory of leptons. Their brilliant creation sank like a lead balloon, to be resurrected much later after 1) 't Hooft and Veltman proved the Salam-Weinberg conjecture of renormalizability, 2) quarks became politically correct, and 3) our experimental colleagues (many of them in this room!) were at last convinced to search for (and to find!) the promised neutral currents.

Despite its many phenomenological triumphs, Abdus was never satisfied with the mere hint of unification offered by the electroweak model. Along with his subcontinental but Indian pal Jogesh Pati, he was the first to exhibit a coherent theory of all elementary-particle forces in all its gauged glory – today's anonymous standard model. And, it was Salam and Pati who insisted that there must be even more broken symmetry with the still-current notion of lepton-ness as a fourth color. Why not $SU(4)$, they asked? Or $SU(5)$, we answered. Why not, indeed?

In October 1979, Abdus, Steve and I got our telegrams from Stockholm, *Time Magazine* quoted Salam as being proud to be the first Muslim to win a Nobel Prize. Steve and I sent Abdus a telegram of congratulation with the comment: "Didn't know that Sadat had converted." In fact, Abdus was the first Muslim Laureate in Science, but to his great chagrin, there has not yet been another. Salam had repeatedly called for renaissance of Islamic Science and an end to the scientifically intolerant attitude of *taqlid*. He would have been a strong supporter of the newly-conceived University of the Middle East. [...]

Incidentally, while all the other Laureates were dressed as conventional penguins, Abdus adorned himself in glorious Pakistani regalia, from a swirling white turban to turned-up golden slippers right out of Arabian Nights. They were immensely uncomfortable, and Abdus took them off as soon as possible. Joan found the slippers fascinating and told Abdus as much. Little did she know that he would send her a brand-new (and equally painful) pair as a keep-sake a few years later. I may remind you that the festivities that began in Sweden culminated at CERN, where Abdus, Steve and I were received as heroes.

I never knew Abdus to drink, to smoke, or to swear. Always a principled gentleman, he was a devout Muslim throughout his life. Let me conclude my brief talk with a few of his own words: "The Holy Qur'an exhorts believers to study Nature, to reflect, and to make the best use of reason in their search for the ultimate. ... The quest for knowledge and science is obligatory to every Muslim from cradle to grave. ... Science is important because of the understanding it provides of the world about us, for the material benefits it can give us, and because of its universality. ... Science and technology are a shared heritage of all mankind. East and West, South and North have all equally participated in their creation in the past as, we hope, they will do in the future, this joint endeavor becoming a unifying force among the diverse people on this globe." Amen!

Abdus Salam's life was gentle, and the elements so mixed in him that Nature might stand up and say to the world: "This was a man!"

68.14 Excerpts from "The Standard Model, Abdus Salam and CERN" by Dr. Carlo Rubbia, European Organization for Nuclear Research, Geneva.⁵

Abdus had an important role in advising on the CERN programs in particular as a member of the SPC. In 1987, when LEP was not yet operational, CERN Council and then DG, Herwig Schopper, created the so-called "Long Range Planning Committee" to define the further steps for CERN. Abdus, together with

⁵ Paper presented at the Special Colloquium in Memory of Professor Abdus Salam at the European Organization for Nuclear Research (CERN), Switzerland, September 23, 1997.

Giorgio Brianti, Pierre Darriulat, Kjell Johnsen, Sam Ting and Simon Van der Meer, helped us in laying the foundations of what is today the present and future of CERN. It was in this small circle of seven people that the names LHC and CLIC were coined and the relative merits and potentialities of the hadron and linear colliders were elaborated and evaluated in depth. I still recall the vivid enthusiasm and the clarity of Abdus' vision on the future of CERN: he used to insist on the relevance of concentrating primarily on key, strategic choices related to fundamental questions. I believe that he has contributed in a major way in defining the next twenty years of CERN strategy in its essentials.

His vision of sub-nuclear physics goes far beyond the accelerator and collider physics and embodies in a very original form, through the so-called "Pati-Salam" model, the unification of all forces. In his vision of Grand Unification, relevant phenomena occur at a lower mass scale (10^{10} 10^{12} GeV) than the standard GUT (10^{15} GeV). I must however confess that the intricacies of this theory have somehow escaped me, purely because of my ignorance of the subject. Though superficially and intuitively, since the nitty gritty details fully escape me, I feel however aesthetically attracted by the intrinsic elegance and originality of his Unification Model. He has always been a strong advocate of proton decay, as the analogue of beta decay in the exploration of the unified phenomenology, at a large scale of energies, which exceeds any reasonable extrapolation of the accelerators.

I have no doubt that Abdus' influence has significantly motivated also the emergence of the modern field of non-accelerator, underground experiments. Personally I owe him my intense interest in searching for proton decay. I am sure that there is no process, which he would have liked to see discovered more than proton decay. I recall his affectionate, repeated insistence, dating back initially as far as the seventies and since then constantly repeated, on the importance of bold, experimental searches for bias-free proton decay. I believe that also in this field, what I would call "the Lagarrigue approach", namely visual techniques and few but fully reconstructed events, in which high resolution is traded for share mass, may be in the long run a worthwhile contribution. This is especially so if one takes into account that the dominant decays might involve neutrinos and strange particles, either because of the forbidden nature of the decay according to some of Pati-Salam like model or because of the pseudo-scalar nature of the effective decay interaction due to a predominance of the Higgs sector.

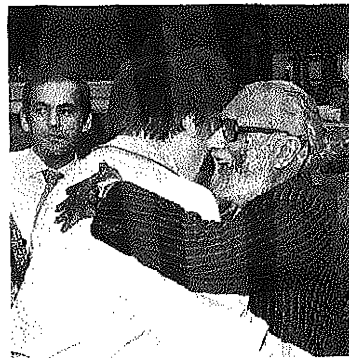
Abdus has been a man of immense faith, both religious and scientific. His main preoccupations have been three: the third World, Islam, and Physics. In his mind Science and Religion are two separate and complementary aspects, which relate to a common, divine design. For him there was no contradiction between Religion, which referred everything to one immutable text and the spirit of Science, which must allow hypothesis, testing and the admission of error and

change. Science and Religion are complementary. He said: "Science and Religion refer to different worlds. Religion refers to things like soul and Allah, not to matter."

He used to underline that one eighth of the verses of the Qur'an praise and remark on Nature and encourage investigation and the intelligent search for Knowledge and that "no verse is in contradiction with Science". He wrote: "The holy Prophet of Islam emphasized that the quest for Knowledge and Science is obligatory on every Muslim." He could even perceive in the Qur'an a description of the Big Bang: "the Heavens and Earth were a mass all sewn up – and then we unstitched them". The Third World Academy of Sciences, his creation, has produced books, which teach modern science through Qur'anic verses, so that both can be thought together in religious seminars.

For Abdus, the word "unification" largely transcends the simple meaning of one of the forces in Nature. It extends to the relationship of Science and Religion and to the necessity of a planetary Science, which should include all people on earth, including the Third World. And such a bold, planetary unification must be performed with the help and the benefits of Science: "Physics is the science of wealth creation par excellence. If a nation wants to be wealthy, it simply must acquire a high degree of expertise in both pure and applied physics."

But most important, (and this is the reason why we are here today) Abdus has been a dear friend to many of us. Though he never stayed here at CERN for long, he was a convinced supporter of what CERN stands for, both in Science and in its international, Cooperative Mission. He has been and he will always remain one amongst the exceptional breed of people – many of them unfortunately no longer with us today – who have powerfully contributed in making CERN successful and what it is today. I would like to conclude and make us feel – if at all possible – as if he is still with us, by showing a couple of pictures taken in the very same Hall in which we are today and which has resonated so many times with his voice and in which we have been charmed by his warm, unique personality.■



74. Embracing Rubbia on his winning the Nobel Physics prize 1984

69

Tributes at The Abdus Salam Commemorative Meeting, ICTP, November 19-22, 1997

69.1 "Welcome Address" by Dr. Miguel Angel Virasoro, Director, The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

I now open this important session of the Memorial Meeting. First, I would like to express on behalf of ICTP and myself our profound gratitude to those of you who have come from all over the world to honor Abdus Salam. I thank especially those who left their country without a president or ministry without a minister, because they have shown the extent to which they care for our founder and everything he stands for. I also thank the numerous representatives of the Italian government because their presence here, which bears witness to the Government's attention to the Centre, is a pledge to keep it alive and creative. I also wish to thank particularly Professor Adnan Badran from UNESCO and Dr. Hans Blix from the IAEA and, finally, to express our most heartfelt gratitude to the members of Professor Salam's family who accompany us and bring with them the warmth of those who were nearest to him.

First of all, the new announcement. As you can see, from now on, the Centre will have a new name, **The Abdus Salam International Centre for Theoretical Physics**, to remind us that the Centre is his creature, that it is the heritage he has left us as much as the Weinberg-Salam theory in another context, as a living monument to his memory.

I would now like to read a message that has just arrived from the Prime Minister of the Islamic Republic of Pakistan. It is indeed very moving for us, who are in this particular place – the adoptive country of Professor Salam – that

This chapter consists of excerpts from selected tributes and messages at The Abdus Salam Commemoration Day celebrated on the occasion of the naming of the International Centre for Theoretical Physics (ICTP) as The Abdus Salam International Centre for Theoretical Physics, November 21, 1997.

Pakistan, his native land, is also present here today through a message from the Prime Minister. It is a letter addressed to the Centre, and to myself, and it says:

I am delighted to learn that the Steering Committee of the International Centre for Theoretical Physics, together with its major sponsors, namely the Government of Italy, the International Atomic Energy Agency, and the United Nations Educational Scientific and Cultural Organization, have decided to rename this Centre as The Abdus Salam International Centre for Theoretical Physics.

Renaming this highly prestigious Centre is not only an honour for the memory of Professor Salam but also for Pakistan. He was a scientist of world stature and built up this Centre over a period of three decades. We are proud of him as the only Nobel Laureate of Pakistan. As the Scientific Adviser to the President of Pakistan for eleven years he rendered invaluable services to his country. As Director of the ICTP, he served a cause, not only of the international physics community but also of the scientists of the Third World. He made outstanding contributions toward expanding the frontiers of human knowledge and promoting science and technology throughout the world. I am sure that the renaming of the Centre will be a source of great inspiration to the younger scientists everywhere.

Muhammad Nawaz Sharif
Prime Minister of the Islamic Republic of Pakistan

This session will be one of reminiscences and anecdotes from those who were near to Professor Salam in different periods of his life, those who knew him well. I am not one of them. Though my life has been profoundly marked by his life and by his projects (in particular, when I returned to Argentina), I only had sporadic contacts with him whenever I came to the Centre. However, I do have an anecdote, and I want to relate it to you because I think it is rather emblematic of his way of thinking.

In 1975, a period already full of threats in Argentina, I had fled from my home country and gone to Princeton. Many colleagues who were still in Argentina had learned that there was a school in oceanography here at the ICTP, and applied for acceptance. For some of them, participating in the course provided an opportunity to leave the country. I took part in that school at my own expense since I was coming from Princeton. One day, Professor Salam saw me in the corridor amidst other Argentineans and said immediately with his swift sense of humor: "Oh, Virasoro! Some people consider you as the second Higgs. They speak about you but they have serious doubts about your existence." Then I explained to him that I had been studying oceanography for some time. His reaction was instantaneous. He said: "Okay, you have switched to oceanography. Now you have to go around and say to everybody that this is the best thing to do." This meant I should turn to other subjects, to more applied fields and so

forth. I had learned (and this was mentioned by Professor Sezgin) that it was very dangerous to be in the vicinity of Salam because he would always find something for you to do!

I have never been very good at selling bibles, not even at selling Mao's red book. I took Salam's advice, however, as part of my idealistic push, and I went ahead and tried to convert some people. With the first two scientists I spoke to, however, I met with complete failure. They were almost offended. So I stopped and went back to Professor Salam. He was not worried at all. He said immediately: "Oh, they were going to be extremely useful in something else in their own countries." And then at that moment I began to realize that in a sense, one has to interpret Professor Salam's thinking, one has to understand what he was meaning at that moment.

He was obviously very keen that research in some applied sciences be done in the developing countries. He labored hard in this direction for a long time. But at the same time, he was very adamant that everyone should work in the field of his choice. And why? This is a very important aspect of his thinking that I would like to reflect upon, because it has to do with the role of the Centre, with the future of the Centre, and also with the past of the Centre. It has to do with the many fights that Professor Salam and many of his collaborators had to face in trying to impose the idea of the Centre.

Professor Salam was absolutely convinced that one of the problems with people coming from developing countries is that the first thing they are deprived of is the right to their own dignity, to their own self-respect. And that is the first thing that has to be rebuilt. His point was, first of all, that we must treat these people as our absolute equals, as people with dignity, so that they are able and allowed to do whatever kind of physics their curiosity brings them to. You certainly know that this concept was opposed violently at the moment of the creation of the Centre. A delegate said: "Why a center for theoretical physics for developing countries? Why shouldn't we give them something for agriculture? Why do you give them – the famous sentence – a Rolls Royce when what they need is a donkey cart?"

There are, I think, many answers to these questions. One of them is provided by my friend Professor Baghdadi, who took part in this battle. To some opponents of the project he said: "Who allows you to deny three quarters of mankind the right to learn about the stars?" And he convinced them. This is indeed a crucial aspect of the Centre.

In this Centre we defend the right of anyone who comes here to study any problem: the problem that is more challenging, the problem that is deeper, the problem that is more basic, because the right to knowledge should be identical for everybody. That is one of the lessons of this Centre, and the reason why Professor Salam has always insisted on excellence. When we organize a school in string theory or in condensed matter physics or in any field, we invite the best lecturers because we must offer the best to those who are coming from all of

these countries so that they can share with us the joy of learning from the best people in the field.

Now, of course the story doesn't end here. Salam had an infinite number of facets and the more you study him, the more new aspects you find. He was also worried about the social responsibility of scientists. When I tried to learn about that, I remembered that we had in the house an extraordinary person, the memory of all of the thoughts of Professor Salam, Dr. Hamende. I went to him and I asked him what exactly Salam had said about this social responsibility. He told me that Salam had made two points.

One is that the scientist in the developing country should be an expert in at least two subjects, not one. He was expecting more, not less, from the people. He said that a scientist, for instance, should be an expert in string theory and he should also be an expert in some other field which is applicable to the situation in which he is living.

And the second point, which is more difficult to decipher, is that the scientist must learn to be a politician. We do have here today a few examples and we should be very proud of the fact that some have been able to make this big step, because we know that for scientists it is a very difficult step.

Professor Salam was also insisting, of course, on the importance of applied science. Yesterday we heard from Professor Mascarenhas about the importance he was giving to medical physics.

I have another anecdote about myself because though I did not have continuous contact with him, since I have been here, I have had a kind of virtual contact, to say it in a modern way. I could perhaps say that I hear voices, but this might be a bit dangerous on this occasion. So let me say I have virtual contact with him. This virtual contact consists of the following: I think about some new project and with my collaborators, we come up with a new idea. We decided, for example, that the new project next year will be a School on the Mathematics of Economics. So then I went to Dr. Hamende who said: "Oh yes, Professor Salam had organized a school on economics in such a year." I sent a letter to some of the professors, and one of them, Ken Arrow, replied, "Yes, I remember a dinner with Professor Salam in Oxford where he mentioned this project to me." So you see that it is very difficult to innovate.

I must say that my situation is like that of the poor physicists of string theory. I do not have the problem of following one track; there is an infinite number of tracks that Salam has left. In any subject, field or direction you can choose, he has also done something or pushed something. So the problem is the selection of the vacuum, as they say in string theory. From this large number of tracks, which one should you choose? We are trying to follow the same line as Professor Salam in many ways.

First of all, we must maintain the level of excellence of the Centre. Believe me, I am finding the same bureaucrats, with exactly the same arguments, who say "Why that, why do you need that, why do you need research in the Centre, why

do you need to get that person who is supposed to go to Cambridge, just take someone else, etc. etc.” In fact, we are trying to establish these new fields which some of our theoretical physicists may find enticing or be interested in learning. In particular, for instance, for the school on economics, we intend to invite people who are already working in mathematics of economics of course, but we shall also reserve a large part of the participation for people who do not have any background in that field, but who are trained in some other field in theoretical physics or in mathematics. The same methodology will apply next year with the course on statistics, and every year we shall try to go into some kind of a new field in the same manner.

So you can see that the directions are all already written, as in the famous Borges library. Everything is already written in the thoughts of Salam. We have simply to choose the appropriate one and that is the direction in which we are going. We owe all of this to Professor Salam.

69.2 “Fulfilled and Not Yet Realized Dreams” by Dr. Paolo Budinich, Professor Emeritus, University of Trieste, Former Deputy Director of ICTP.

The establishment of the International Centre for Theoretical Physics (ICTP) at Trieste in 1964 and of the several international institutions, which followed thereafter is due to a series of accidental but well correlated events. The first was Abdus Salam's participation, in June 1960, in one of the international symposia on elementary particles and field theory which we organized at the Castelletto of Miramare, where he discussed $SU(3)$ symmetry and renormalization. The second was his proposal, in September of the same year, at the General Conference of the International Atomic Energy Agency in Vienna, for the creation of an international center for physics under the flag of the United Nations. I accidentally learned about it a few days later from Edoardo Amaldi in Rome. This early notice gave us the possibility of convincing our Government to immediately submit the Italian candidature of Trieste for such an institution. As a result of these happenings, after three years of difficult diplomatic battles which we, Italians, fought in Vienna together with Abdus Salam, the ICTP was inaugurated in Trieste in 1964 under his direction. Without that timing of events the ICTP would have been established elsewhere in Italy – in Florence or Naples – or otherwise in Copenhagen or in Vienna.

His scientific prestige, together with his drive and energy, determined the course of ICTP's history during the thirty years, which followed. This has been a history of difficult battles, which I have had the privilege of fighting with him. We obtained rewarding victories but also suffered from defeats, which more than victories, contributed to generating and strengthening a deep friendship between us.

The best tribute to his memory, which I can think of is to try to convey to you his and our dreams during those thirty years, especially those which have not fully come true as yet. I hope and I wish that, in order also to honor his memory, those dreams may be taken up as a commitment by those who now bear the responsibility of supporting this enterprise.

Since the first years of our operation for the benefit of scientists in developing countries – for the benefit of the poor as Abdus used to say – it clearly appeared that a lot could be done to remedy their isolation as well as the lack of consideration by local authorities, which were the main causes of the deleterious brain drain. However, the immensity of the problems, compared with the means at our disposal, became quickly apparent. At best we could produce a drop of benefit in a vast ocean of needs and difficulties. So much so that it was absolutely necessary not only to strengthen the ICTP, but also to replicate it, in other subjects, elsewhere. Salam convinced the United Nations Industrial Development Organization (UNIDO) to copy ICTP for biotechnology. The result was the International Centre for Genetic Engineering and Biotechnology (ICGEB) which we finally succeeded in bringing to Trieste. Some replicas of the ICTP have been created in Colombia, Scotland, the US and recently, perhaps the best one, in Korea headed by C.N. Yang. But more are certainly needed.

When he visited the ICTP in the seventies, the Secretary General of the United Nations, U Thant, took it as a model when he proposed and created the UN University which, despite our efforts to bring it not far from the ICTP, went to Tokyo (Japan offered 100 million dollars to host it there). Afterwards Salam tried to bring the Faculty of Science of the UN University to Trieste. This project was taken over by our Foreign Minister, who obtained the warm consensus of the UN University.

In addition to ICGEB, several other national and international scientific institutions were created in the Trieste area in the wake of the great success and prestige of the ICTP: among these, the Synchrotron Radiation Laboratory, the International School for Advanced Studies, the Research Area. Salam had hoped that their action would be coordinated and partially devoted to the benefit of the Third World. The UN University Faculty of Science could have served this purpose, and perhaps this project could still be revived.

In this framework he also conceived the creation of the International Centre for Science (ICS), run by UNIDO and devoted to high technology, new materials, earth sciences and environment, which should have developed its own experimental laboratories or others based in the existing scientific institutions in Trieste; but for the moment, the ICS, as conceived by him, is still at the stage of a project.

Salam's main concerns were actions in the framework of science and science literacy in the Third World, and the enhancement of the South-South cooperation. To this end he created, through the Trieste International Foundation of which he was elected president, the Third World Academy of Sciences

(TWAS), an instrument of very high prestige whose great potential has not yet been fully exploited. The Academy is privileged to have among its members several Nobel Laureates. I shall mention only one project of TWAS which Salam hoped to see implemented: the project of granting to each one of the developing countries at least one complete scientific library. He obtained a promise of support for this project from the World Bank. Now by means of computers, informatics and Internet, which, I understand, ICTP is now developing and extending to the Third World, that project could perhaps be more easily realized. It should be felt as a moral duty by the rich western civilization which, after all, owes its birth to a library which was seated in a now developing country, that of Alexandria in Egypt. To start with, we proposed a pilot project for five Mediterranean countries to our government. We also obtained the interest of our President Scalfaro for this project, but for the moment we are only in a phase of promises and intentions.

I mentioned just some of Abdus Salam's dreams. There are other deserving ones, which are illustrated in his book *Ideals and Realities*.⁶ I do hope that the concrete results of the action of ICTP after thirty-three years of operation will persuade the United Nations' agencies as well as our government to give the possibility to the Abdus Salam International Centre to make his dreams a reality for the benefit of those who need and deserve it. I am convinced that this would be the best possible way to honor Abdus Salam's memory.

69.3 "My Association with Abdus Salam" by Dr. Luciano Bertocchi, Former Deputy Director of ICTP.

This is the story of my relations with Abdus Salam, which were quite close for almost thirty years, and very intense for the last twenty. The first time I heard the name of Salam was in the fall of 1956, when, as a young student, I was preparing my Italian Master's thesis on dispersion relations. My supervisor gave me a copy of the lecture notes on dispersion relations which had been delivered by Salam at Rochester. These were hand-written notes – they appear in the list of his publications kept at our library as publication No. 24 – and the way they were written was very typical of Salam's approach and style.

Even for formulae, although the beginning as well as the final result were correct, the intermediate passages were full of mistakes; but the final result was right. This was typical of Salam: to be able to pick up, in physics as well as in all other domains, the most important points, and to look at them very carefully, neglecting the less important details, provided the final result was correct.

I met Salam for the first time only a few years later, on the occasion which has probably been the most important one of the scientific future of Trieste as the

⁶ Abdus Salam. 1984. *Ideals and Realities: Selected Essays of Abdus Salam*, edited by Z. Hassan and C.H. Lai. First edition. Singapore: World Scientific Publishing Co.

City of Science: the meeting organized by Paolo Budinich at the Castelletto of Miramare, with the participation of Salam. (Six of these persons are with us today: Budinich, Fubini, Amati, Furlan, Tonin and myself.)

I later heard about the idea of the Centre during my stay at the University of Turin, from 1961 to 1963, and I vividly remember the lively discussions we had there on this subject, and the great interest with which the idea was received by the community of the young Italian theoretical physicists. We all clearly perceived how great this opportunity would be, not only for the developing countries, but also for the Italian physics community and for Italian science in general.

The existence of the Centre in Trieste was the main reason for my choosing Trieste University after my stay at CERN from 1965 to 1967, rather than returning to my alma mater, the University of Bologna. It was clear at that time that Trieste would offer, to a young theoretical physicist, better opportunities than any other Italian university.

The last twenty years are those in which my contacts with Salam were particularly intense. The way he recruited me was also an example of his behavior. I had been given by Salam a task of organizing one of the first training courses of the Centre. One day, Cal O'Neal, who was at that time our link with the Agency, came to my office while I was working on preparing the selection of candidates. It was later evident that he had been sent there by Salam to examine my work. The report must have been positive, since immediately after I was offered the task of coordinating all the Centre's programs and later the job of Deputy Director.

But afterwards Salam demonstrated his trust by delegating many responsibilities to me. His mode was: "This is what I want: find the way." What he required from managers was not to bend the rules; it was to find within the existing and applicable rules the way of realizing what he had in mind.

The twenty years I have spent in close cooperation with Salam were the years of the Centre's development, when most of the present programs were added to the initial schemes.

These were for us years in which we were cooperating closely, but also fighting each other; but those fights always ended in a clear mutual understanding. It was a period of hard work, of fascinating new projects but also of severe difficulties. We experienced great satisfaction, but also went through moments of deep frustration, when financial difficulties due to delays brought the Centre almost to collapse.

However, when Salam had to physically leave the Centre, those difficulties had been overcome, and he would be happy to see that now the Centre is a mature institution, which enjoys, to a large extent, stability and autonomy.

Salam was also a man of great humanity, although this aspect of him might have been hidden by his energy, by his will to do more and more and to request the same from those who were working for him.

He always dealt in the same way with heads of states and with the poorest and youngest scientists; we all remember him standing at the entrance of parties, shaking hands with all the individuals, from Nobel Laureates to young physicists. His favorite sentence was "no man is an island", meaning that we all have to cooperate.

To give you one example of his humanity, I will mention the following. A few years ago, a thief entered the villa where he was living and most of his medals were stolen. At the same time, he also entered the home of the caretaker, stealing his money. Salam's immediate preoccupation was to reimburse the caretaker what he had lost; and we had indeed to find a way within the rules to do exactly that.

What impressed me most about Salam were two aspects.

1) The capacity of switching very rapidly, almost instantly, from scientific to managerial aspects, and especially vice versa, from managerial to scientific, always immediately identifying the key points.

2) His great enthusiasm: his will to try, to explore new avenues, to launch new projects, even when he was not sure of success.

In physics, as well as in managing and creating new things, he always preferred to do one hundred things, ten of which were wrong, eighty right but normal, and ten excellent, rather than carefully analyzing a new idea before trying, and in this way avoiding failures by doing only ten things, nine of which were right and normal, and only one excellent.

Another aspect of Salam was his desire for learning. For him learning was as important as creating. I shall always remember one of the last discussions I had with him concerning physics, when his illness was already advanced,

He was asking me whether I knew a paper in which corrections to the semiclassical Wentzel-Kramers-Brillouin (WKB) approximation were discussed, since he felt that he would need higher corrections to semiclassical calculation in what he was doing at that moment in biophysics. Since we – Fubini, Furlan and myself – had written a paper on the subject about thirty years ago, I gave him a copy of that article. The day after he called me again, to discuss details in our paper. One day for him was more than enough, and by that time he already knew more about the subject than I did.

Among his great successes, two are the summits, and both now bear his name: the standard model in physics, the Salam-Weinberg model, and the creation of the ICTP, the Abdus Salam International Centre for Theoretical Physics. I shall not list in detail the things he did not manage to achieve, but will just mention one: the creation of twenty new international centers to be located in the Third World.

I saw Salam for the last time in the Spring of 1995, when we visited him in Oxford. His body was no longer obeying his spirit, which was however still very vivid. When I was telling him about the Centre, his eyes were sparkling. And I will always remember him in this way: enthusiastic, and eager to learn and to do.

I shall end by saying that I consider myself fortunate, since I have had the opportunity of working for so many years in such close contact with a person like Salam. And many people here should also consider themselves as fortunate, for the same reason, as I do.

69.4 “From the Advanced School for Physics to the Synchrotron” by Dr. Luciano Fonda, President of the Faculty of Sciences, University of Trieste.

I met Abdus Salam in the summer of 1960 at Rochester where we were both attending the big Conference. I was still doing research in high-energy physics at that time and, with him, I belonged to a small working party of physicists trying to understand the subtle world of particle physics. Feinberg, Gürsey, Marshak, Regge, Weinberg and a few others were also there. I was immediately impressed by Salam's deep insight into physical problems and by his promptness in jumping from one item under discussion to another.

However, it was four years later that he established a working relationship with me which quickly developed into a long-standing friendship. He had appointed me as the first consultant of the Centre, in the field of nuclear physics, and consequently, there were many occasions for interaction when we were planning the organization of that field research. Moreover, Paolo Budinich had appointed me as Director of the Advanced School of Physics. The school was supported by the IAEA, UNESCO and the University of Trieste and welcomed fellow participants from developing countries. In this connection I gained a lot from his experience as a teacher at Imperial College for establishing the fundamental topics (bread and butter as he defined them) and the more specialized courses. The School remained in operation for fifteen years until its activities, courses and fellows were transferred to the newly born International School for Advanced Studies (SISSA). Throughout this long period my interactions with Abdus were continuous. Of course, we had some arguments since, because of stringency of funds, we were unable to cover the many fellowships that I wanted to have from the Centre but when he was wrong he would always write to his “brother”, as he affectionately used to call me, a letter of apology, letters that I still keep because they bear witness to his kind-heartedness, to his great generosity.

Later, I had the chance to know him more deeply from a scientific point of view. It was the year 1974 and I received from the Nobel Committee, like other

colleagues in our university, the request to propose a candidate for the Nobel Prize. I studied in detail all his papers, which were related to the electroweak unification of forces and went directly to him to understand some subtle passages of the theory.

At the time I was surprised at his capacity to work and do research for hours and hours untiringly without vacation, with the only aim of reaching the final result, the final theory. I was also impressed by his sense of history. He had the reminiscence of the Islamic past civilizations and of the great Islamic philosophers imprinted in his bones. And then I became aware of his great humanity, of his donations to the poor without making himself conspicuous. As a matter of fact, only a few people know that with money he received from the prizes conferred upon him, he constituted a fund for donations of instrumentation to the physics departments in developing countries. Together with John Strathdee, I was in charge of endorsing his checks. These were extremely generous actions, which he carried out without showing off.

In later years, starting from 1980, he strongly encouraged me to establish in Trieste a Synchrotron Radiation Laboratory. He provided me with actual help with some ministers, like Romita and Andreotti, and also spoke favorably of Trieste in England where I directly experienced the results of his action concerning the 6 GeV European machine that ended up in Grenoble. For the 2 GeV smaller machine of Elettra, now functioning on the Carso plateau, a few kilometers from here, he always pushed the idea that scientists from developing countries should have the possibility of doing research there and he proposed the construction of two beamlines at Elettra for their benefit. This is something which still has to be implemented. And again, in those circumstances, he was totally unselfish. In fact he told me that he was not afraid that the Italian Government would cut the Centre's funds when the project for building Elettra would have been approved. This was proven by the great joy with which he embraced me after the announcement I made in this very room on July 25, 1985 of the final decision taken by Minister Granelli on this matter.

I was really moved that day by his spontaneous gesture and I am moved today thinking that he is no longer here to spur us on with his vision in which poor scientists would benefit like the rich.

69.5 "Abdus Salam and the Department of Theoretical Physics"

by Dr. GianCarlo Ghirardi, Director, Department of Theoretical Physics, University of Trieste.

For many years I have been in close contact with Professor Abdus Salam. I came to Trieste in 1963, and so I can say that I have been here throughout the whole period of his Directorship of the ICTP.

My relationships with him have been of at least three different kinds:

1) Administrative. In the above period I have been the Director of the Institute and of the Department of Theoretical Physics of the University of Trieste for thirteen years. Thus I had almost daily interactions with him concerning the collaboration between the ICTP and the University of Trieste. He had always valued enormously the presence of the University in the Miramare system and the tight scientific links between the two institutions. I think that all of us who belong to the University have to be grateful to him for his high esteem of ourselves and our institution.

2) As a consultant. I have been the organizer and/or local organizer of many activities from 1976 to 1990. Seven years ago he asked me to head the Associateship and Federation Arrangement Programs, a great honor for me, which allowed me to contribute to the attainment of the ideal of the Centre which I fully share. In relation with this direct involvement, I had the opportunity of witnessing day by day his commitment to running the ICTP in the best possible manner, his continuous desire to see the prestige and the absolutely peculiar and extremely useful role of the Centre, universally recognized among all scientific institutions of the world. The two programs that he had launched had two purposes for him: on the one hand the primary purpose of fighting the isolation of young promising scientists in the developing world; and, on the other hand, to make the existence and relevance of the Centre adequately known in all countries in order to attract young scientists from the Third World. Consistently with these objectives, he also wanted to make the industrialized countries aware of the high scientific level and the relevant aims of this institution, in order to obtain the collaboration of prestigious scientists for the activities of the Centre, and to convince the governments of such countries to imitate the generosity of Italy in supporting this wonderful institution.

3) As a scientist. I could say many things about this relationship. It has been extremely stimulating for me to interact with such a genius. But in place of celebrating his outstanding contributions to science which will surely be stressed by most of the speakers, let me tell you a story which testifies in an extremely significant way to his desire to give a very good image of the ICTP, his deep scientific insight and his open-mindedness.

As some of you may know, I have been deeply involved in investigations about the foundations of quantum mechanics for many years. Abdus had a good opinion of me but he was not particularly interested in this subject. He told me several times: "Do figures not come out all right when you use the theory – quantum mechanics – in its standard formulation, to calculate the outcomes of any actual experiment? Then, what are you worried about?" Such an attitude is perfectly understandable in his case: when, day by day, a genius like him is elaborating new fundamental concepts which lead to a radical improvement of our understanding of nature, he has to be extremely practical and concrete. The reflections, both mathematical and epistemological, will follow and will be the task of other people.

However, some years ago Sir Karl Popper, the world-wide known philosopher of science, was visiting the Centre. I remember Abdus calling me in his office and saying: "On this occasion I want you to make a long, incisive comment on the speech of Popper, so that it will be clear to everybody that at the Centre we have adequate competencies in all fields related to science." I knew the writings of Popper on quantum mechanics very well, and, with my deep respect for his philosophical work, I must say that I also knew very well that the ideas he was going to present in the seminar were not correct. Hence, I said to Salam, "I am ready to express my views, but I warn you that I shall be very critical about what he will say; I am a little worried about attacking such a famous thinker in public." Then Abdus replied: "You have no reason to be worried, I have full confidence in your competence, and you must go on." So, after Popper's talk I went to the blackboard and I proved, in the simplest and most direct way I could, why his proposal of a "gedanken" experiment, which would imply either the falsification of quantum mechanics or of special relativity, was basically wrong. He did not counter argue, he simply stated: "I am not very expert in the technical and formal aspects of the theory, but I remain convinced that if quantum mechanics is true, then you can send faster than light signals."

The following day Abdus called me and thanked me for my comments. He added that he also wanted to thank me for having made clear to him some interesting problems to which he had never paid attention. This is, among the recognitions I have received during my scientific career, one of those I value most. I have mentioned it only to highlight precise evidence of Abdus' desire to maintain the ICTP's prestigious image, his incredible capacity to grasp a subject immediately even if he was not familiar with it, and his open-mindedness which made him recognize that he could find something interesting even in a field which he viewed with a noteworthy amount of skepticism.

69.6 "INFN and the Centre" by Dr. Nello Paver, Director of the Trieste Section of the Italian National Institute of Nuclear Physics (INFN) on behalf of Dr. Luciano Maiani, President of INFN.

With much regret, Professor Luciano Maiani, President of the Italian National Institute of Nuclear Physics (INFN), is not able to take part in this memorial ceremony. He has asked me to represent him and the INFN, and to address the meeting on his behalf. I feel honored and privileged to carry out this pleasant function.

As physicists actively working in nuclear and particle physics, we owe a great deal to Professor Salam's everlasting scientific work, which has been really influential for the progress of our field and has led to the present understanding of the subnuclear world. However, apart from his outstanding contributions in physics, I feel we should above all recall here other traits of his unique personality and, first of all, his contagious optimism as a rule of life. He was a

very pleasant and social man, with surprisingly broad interests. He was genuinely concerned with the people, their activities, their way of life, their needs and so on. To add just one more recollection to the many others already presented here, in physics discussions or seminars he was always able to make quite pertinent – and often tough – points on the subject at issue, yet in such a polite and tolerant way that the interlocutor (or the speaker) in any case could feel at ease, even when the seminar had been tedious!

A passion for transferring scientific knowledge to the developing countries was a distinctive aspect of his whole life, and the creation of the International Centre for Theoretical Physics (ICTP) has been one of his greatest successes in this regard. [...]

We are proud that the Italian Government was far-sighted and understood the potential of the idea, and that it decided to support the ICTP generously. The INFN collaborated informally with the Centre right from the beginning. This collaboration was formalized later on through agreements covering participation in activities of common interest and exchange of scientists, which proved extremely rewarding over the years.

Another aspect of Professor Salam's personality I wish to recall is his faith in the role of the fundamental or basic sciences – which of course include theoretical physics and pure mathematics – in the development process. He obviously very well knew that social and economic progress depends on a multiplicity of factors including the mastery of "sciences in application", as he called them, and of high technology. In fact, he promoted many programs pertaining to these categories at the ICTP. However, he considered that research in the basic sciences represented a great "added value" from the cultural point of view and an indispensable requisite for successful research work in applied sciences and technology in emerging societies as well as in the industrialized world. In these days when severe cuts affect budgets for basic sciences and when society seems (to me) to prefer immediate financial returns to intellectual and educational benefits, we certainly miss a strong and eloquent defender of fundamental science.

Professor Salam was also very interested in international problems and in the role of science in politics and society. He was surprisingly well-informed about what was going on around the world and had fine, and global, intuitions in this regard. In particular, the present status of science in the Islamic society occupied a special corner in his vision of the world. [...]

We thus remember Professor Salam with greatest admiration and love. Perhaps the best way to honor his memory is to continue our scientific research and do it to the best of our possibilities, and eventually try to realize, in part at least, some of his great visions of science and life.

69.7 "At the Service of a Great Scientist and Administrator" by Dr. André-Marie Hamende, Former Senior Staff Member of the ICTP.

First of all, I wish to thank the organizers of the commemoration ceremony for this opportunity to pay homage to Abdus Salam, the man who has been my supervisor from 1964 to 1994.

Abdus Salam was a great physicist and a great science administrator. His exceptional merits in science were sanctioned by the Nobel Prize nearly twenty years ago while the institutions created by him in Trieste speak for his extraordinary abilities as an organizer. Since other guests will talk about his work in physics, I shall focus on only a few of the many episodes which, during my thirty-year association with him, have left a profound imprint in my memory because of their impact on the course of development of the Centre and on my professional life.

Abdus Salam was moved by a passionate zeal for physics and for the social and economic emancipation of the developing countries. He was of course aware that science was not everything in this context but he strongly believed that science had an essential role to play in the process of economic development and that, according to his own words, "science transfer must always accompany technology transfer". This conviction which transpires in many of his writings and which is at the root of all the institutions created by him in Trieste should not be considered as a naïve *Weltanschauung* promoted by a specialist but rather as an expression of his irritation and impatience against what he perceived as an indifference or absence of vision in some of the political circles of the developing countries.

The first years of the existence of the ICTP were crucial for establishing its credibility and for dissipating the skepticism about its usefulness of some of the IAEA Member States. It was then that Abdus Salam could display his extraordinary capacity of mobilizing the friendship and the competence of eminent scientists like A.O. Barut, C. Fronsdal, M. Rosenbluth, R. Sagdeev, Nishijima, and of creating a stimulating research atmosphere while pursuing his own work and supervising the research of a group of young and brilliant physicists from the Imperial College. As Professor Kibble has said that the study of symmetry in elementary particles was very popular in those days and the ICTP made important contributions to this sector. This was also the time when eminent scientists like A. de-Shalit, C. Villi, S. Lundqvist, N. March, J. Ziman, F. Garcia-Moliner became involved in the enlightened guidance of the activities in nuclear and in condensed matter physics.

The first episode dates back to 1968 a few months before the Centre moved from its first home at Piazza Oberdan to this building. Abdus Salam and P. Budinich called me and told me that out of the three professional posts, which had been necessary in the establishment phase, only one would be maintained and that I should therefore combine my present duties with administration. They said that every one should be polyvalent and able to carry out as many tasks as required by the organization. Some time later, Abdus Salam added that he would reject any budget proposal where what he called "overheads", or the cost of the administrative and technical staff, maintenance, heating and air-conditioning and so forth, would exceed 25-30% of the total. This was very drastic indeed but indispensable for the survival of the ICTP, and implied very strict measures on the recruitment, proper grading and promotion of the administrative staff. On that day, I probably did not fully realize that we were at the beginning of a period of austerity and of very slow expansion which was to last until the second episode I wish to talk about that is the Nobel Prize. In fact this episode is the Big Event at the ICTP.

The Nobel Prize to Abdus Salam is definitely the milestone in the history of the ICTP. Many of us remember that day of October 1979 when Abdus Salam returned to Trieste after the announcement of the Prize and the enthusiasm as well as the expression of affection and admiration, which welcomed him at the entrance of this building, in the city and in the community from the developing countries. In the months, which followed, the University of Trieste conferred the diploma of honoris causa upon him, he was made honorary citizen of Trieste and was received by all the local authorities. This Prize was the long awaited recognition of Salam's outstanding achievements in physics and, as an indirect consequence, the acknowledgement of the validity of his ideas on the international cooperation in science and of the usefulness of the ICTP. For the Centre, it meant a first leap in the financing of its programs.

It took nearly a quarter of a century to give the Centre the profile we are now accustomed to: stable research groups, forty to fifty high level meetings every year in a large range of subjects with computational support when required, a conspicuous number of Associates and federated institutes, external activities, research fellowships in Italian laboratories. A few figures show that the Nobel Prize was determinant for the expansion of the Centre. From 1970 to 1979, the increase in financial resources came mainly from the IAEA and UNESCO and allowed for an increase of activities (expressed in person/month) of about 3.5% every year. After the Nobel Prize until 1984, the average annual growth rate jumped to 9% thanks to increased contributions of the IAEA and the Italian Government. In 1987, the Italian Government became by far the biggest sponsor of the ICTP. All this was due to the capacity of Abdus Salam and his deputies Paolo Budinich and Luciano Bertocchi to convince high-rank international officials, ministers of the Italian Government and members of the Parliament,

local authorities and Ambassadors of the genuineness of their ideas, and, of course, to the support of the international community of scientists.

The third episode refers to a visit, in 1981 or 1982, of the Minister of Foreign Affairs during which the second quantum jump in the financing was announced in this lecture hall. Professor A. Zichichi who was accompanying Minister G. Andreotti said that the Ministry of Foreign Affairs of Italy had decided to raise its contribution to US\$ 5 million. This was somewhat expected and, of course, most welcome but the surprise came immediately after when Minister Andreotti announced: "I am sorry to correct my friend Antonino, but the contribution will be ten million." I shall never forget the smile of Abdus Salam, the incredulous face of Luciano Bertocchi who had turned to me and a thunder of applause which followed. This was the dawn of a new era for the ICTP which materialized in 1987.

Let me now say a few words on my first encounter with Abdus Salam. This happened in July 1962 on the occasion of the International Seminar on Theoretical Physics organized by him under the auspices of the IAEA in Miramare. The IAEA had sent me there to assist the Scientific Secretary, A. McReynolds, after a sequence of fortuitous circumstances. During the six weeks of the seminar, I spoke only two or three times to Abdus Salam but, much to my surprise, on the eve of my return to Vienna, he invited me to join him and two lecturers, Marcel Froissart and Abe Paris, for a dinner at the Hotel Riviera. At the end of the dinner, he told me: "Hamende, when the center will be created, you will work with me. I shall write to Director General." This is how the course of my life changed radically. I joined the ICTP two years later. At the seminar, I met P. Budinich, S. Fubini who was a lecturer and other friends who are here today: Harun-ar-Rashid, J. Nilsson, G. Furlan.

Abdus Salam was a very rich and generous personality. He was exacting for himself and with his collaborators. He succeeded in inculcating in the scientific and administrative staff a sense of mission to which everything was subordinated. To many of the scientists from the developing countries and particularly to those involved in the more fundamental disciplines of physics and mathematics, he advised to cultivate another subject of a more applied nature (the second string), to contribute to the dissemination of science at a popular level and to take an interest in the economic and social progress of their country. To the administrative and technical staff, he said that everything should be done so that the visitors would gain the utmost of their stay at the Centre and never waste their time in useless bureaucracy. As for myself, whenever he gave me instructions, he left me ample freedom in the execution. Here, I must mention a trait of his character. He was at times very impatient and each time he had been somewhat rude to me, he would send me a note of apologies accompanied by a small present. I must also mention that I have always been impressed by his

“multitasking” capacity: he could switch from one subject to the other with the velocity of lightning.

69.8 “Abdus Salam and the Experience of Mystery” by Dr. Sergio Fubini, University of Turin and CERN Theory Division.

I am deeply honored to have been invited to speak in the memory of Abdus Salam, an outstanding scientist and a very great man.

After all the talks, it is very hard to say anything new about him. However, I still found something, which is one of the elements of Abdus Salam’s fame. I am referring to one of his books: *Ideals and Realities*. I read it three times and from this reading, learned a lot from Salam. For instance, about the scientist’s sense of wonder for the beauty and for the symmetry of nature, he wrote the following which clearly characterizes his way of thinking:

“Now if there is one hallmark of true science, if there is one perception that scientific knowledge heightens, it is the spirit of wonder; the deeper that one goes, the more profound one’s insight, the more is one’s sense of wonder increased. This sentiment was expressed in eloquent verse by Faiz Ahmad Faiz:

*Kai baar iski khaatir zarre zarre ka jigar cheera
Magar yih chashm-e hairaʼi jiski hayraani nahiñ jaati*

(Moved by the mystery it evokes, many a time have I dissected the heart of the smallest particles.

But this eye of wonder; its wonder-sense is never assuaged.)

In this context, Einstein, the most famous scientist of our century, has written: “The most beautiful experience we can have is one of the mysterious. It is the fundamental emotion, which stands at the cradle of ... true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed. It was the experience of mystery – even if mixed with fear – that engendered religion. A knowledge of the existence of something we cannot penetrate, our perceptions of the profoundest reason and the most radiant beauty, which only in their most primitive forms are accessible to our minds – it is this knowledge and this emotion that constitute true religiosity; in this sense, and in this alone, I am a deeply religious man.”

A point I wish to stress is that a very important way of honoring the memory of a great man is to continue and strengthen his work. An American folk song says: “His body is in the grave but his soul is marching on.” So the spirit of Salam is still here and we have to follow it from where it is, first in this Centre which is his Centre, and in his successor, an outstanding scientist from Argentina. Salam’s spirit is also in the new center in Korea, in the new developments in Venice and in the Middle East and where we, in Turin and in Geneva, are trying to build up good scientific relations between the scientists of the Region and with American and European scientists.

To conclude, I wish to quote a sentence from Disraeli, the great British statesman, which Salam cited many times and which reads: "There is nothing strong and more lasting than an idea whose time has come."

**69.9 "Abdus Salam and Africa" by Dr. Daniel Akyeampong,
Department of Mathematics, University of Ghana.**

My thirty years of close association with Professor Abdus Salam began in October 1963 when I entered Imperial College of Science and Technology, London, initially to take the diploma coursework in mathematical physics before embarking on the Ph.D. studies. Salam taught the class in group theory. His lectures were very popular and one had to go early to find a seat. Following my successful completion of the coursework in the summer of 1964, he invited me to his office one day, and told me about a new international center for theoretical physics to be established in Trieste, Italy, which he was going to direct in the autumn of the same year, and the reason why he expected me to join him there. That was how in October 1964, Jimmy Boyce, Ray Rivers and myself became the first postgraduate students of Salam in Trieste, and so had the honor of joining the post-doctorate colleagues Bob Delbourgo and John Strathdee to become members of the group that was christened by Ms. Jean Bouckley and Ms. Miriam Lewis as "the Salam boys".

The first years of our stay in Trieste were indeed exciting: Salam had just proposed $U(6,6)$ as a possible symmetry group of nature and all eyes were on the Centre. Salam worked hard to get the Centre known worldwide and we were naturally infected by his ceaseless dedication. We had our lunches together at the Mensa dei Ferrovieri with him at the table head, John and Ray at one side of the table and Bob and Jimmy on the other, with me deciding when to sit next to Ray or to Jimmy. These became physics working lunches – with paper napkins serving as writing equipment – and each session usually ended with several suggestions from Salam or Bob or John for us graduate students to pursue later. The excitement and enthusiasm Salam displayed were infectious; and later when I had the privilege to collaborate with Delbourgo, who was my unofficial supervisor, it became clear that he was indeed a chip off the old block.

An association with Professor Salam is really a life-long one. When in September 1966 I went to say good-bye, I thought that was going to be the last time I would see him. However, a few months after my arrival in Ghana, I received a letter from him informing me that I had been made an associate of the Centre.

As an associate, I spent three months at the Centre after nine months of teaching and research at home. I do remember very vividly the standard questions he would ask on each visit, when I showed up to report my presence.

"Oh, you are here?" he would say. "How is Ghana? Have you found a place to live? Where is your office?" And then finally "What are you working on?" Then he would say "Strathdee and I have been working on this interesting problem. Why don't you see him for more details?" It was through the Associateship Scheme which was extended several times for me that I was able to maintain a close working relationship with him, and for that I shall be forever grateful.

My last meeting with him was in the summer of 1993 when I went to say good-bye to him at the end of a visit at the Centre. It was an emotional one with both of us embracing each other and not saying a word as if we knew that it was to be the final farewell. In November 1996, I heard on the BBC that he had joined the ancestors.

Professor Salam in his time played many parts on the world stage. But for us in Africa, he will be remembered, I am sure, for having made it possible for our citizens to continue to conduct research at a high level while at the same time contributing at home. His conviction was that since science is a shared heritage of mankind, all of mankind should participate fully in its creation. But this not being the case at present, he felt that the rest must help to facilitate the internationality of science, especially since, in Salam's words, "East and West, South and North have all equally participated in its creation in the past as, we hope, they will in the future." [...]

The unequal opportunities which exist in the world of science engaged Salam's attention and he used his influence and prestige to try and correct the imbalance. The existence of the Centre shows how much can be done with determination and goodwill all around. Because of his own love for symmetry, it was his hope that the African scientist would bring into creative effect his own cultural emphasis on beauty, elegance and rhythm, just as other scientists are influenced in their work by their cultural traditions. This hope could be fulfilled given the continuing support of the Centre.

In its early operation, the number of African scientists at the Centre was low indeed. There were only two, Skyim-Kwandoh and myself, both from Ghana. We were to be joined later by Taha and Ahmed from Sudan, Maduemezia and Nwachuku from Nigeria and later still, when Condensed Matter Physics became one of the recognized programs of the Centre, by Allotey from Ghana and Williams from Nigeria. The Centre has helped to sustain quite a sizeable number of active African mathematicians and scientists, many of whom unfortunately are no longer at home to train the next generation of scientists as envisaged by Professor Salam. These have joined the infamous brain drain – the tide that Salam strove so vigorously to stem – not because they wanted to, but because unfavorable socio-economic conditions so familiar to Salam made it difficult, if not impossible, for these scientists to be creatively productive in their own countries.

Was Professor Salam disappointed by this turn of events? Ever the optimist, Salam knew that the political and economic situation in our part of the world will take some time to improve. In the 1980s, a coup d'état brought to an abrupt end a Regional College organized by the Centre in an African country. Subsequently, when he was informed that another College in an African country had been abandoned, also because of a coup, Salam's immediate reaction was "Now I know how to export coups d'état!" These setbacks may plague the developing world into the near future, but that is no reason to prevent us from bringing some of the Centre's scientific activities nearer to home so that many more people will benefit from these collaborations.

Africa has indeed appreciated what Salam did for her sons and daughters, and this is evidenced by the number of honors bestowed on him by its academies – including the African Academy of Sciences; the Academy of the Kingdom of Morocco; the Ghana Academy of Arts and Sciences – and by the esteemed recognition of many of its universities – including Maiduguri in Nigeria; Khartoum in Sudan; Nairobi in Kenya; National University of Benin in Cotonou, Benin; University of Ekpoma, Nigeria; Yaounde, Cameroon; Ghana – and by the several audiences granted him by heads of state throughout Africa.

Salam has bequeathed to us knowledge and compassion. So what can we do to ensure that his dream, his ideal, shall never die? ICTP can contribute by continuing to make it possible for many more scientists from the developing countries to meet and exchange ideas with their peers here. And the international community at large can contribute by building other centers for highly trained researchers in other fields, and locating such facilities strategically to enhance their accessibility. Building bridges to ensure the universality of science will be a lasting monument to his memory.

But above all, it is the man's vision – which was his humanity – that I fervently hope the Centre will keep alive perpetually, like a flame.

69.10 "Teacher, Colleague and Friend" by Dr. Robert Delbourgo, Department of Physics, University of Tasmania, Australia.

Salam assumed many different roles in my life: initially as a teacher, both undergraduate and postgraduate, then as Ph.D. supervisor, then as "boss" (here at ICTP), and finally as a good colleague and close friend.

My first contact with him was as a teacher. Even though Salam did not relish lecturing, I found him to be one of the most inspiring teachers, his breakneck pace notwithstanding. And he mixed well with the students at Imperial. In fact my first contact with him was in 1958 when he came to a dinner where students got to know the staff. He wasn't too busy for that sort of thing and he always found time for students, that is until he got deeply involved in the business of

founding the International Centre. Many of you will know that Salam was a totally unpretentious person. Curiously, he quite enjoyed English refectory food (can you imagine that?) and was at his happiest when mixing with the "plebeians" (as he called the student body) in contrast to the "patricians" (or staff). On one occasion Bruno Zumino was visiting us from CERN and Salam insisted on taking him for lunch to the student cafeteria rather than the Staff Common Room, as he preferred to rub shoulders with the "common man". I think this tells us something about his personality.

Naturally, he was a great source of inspiration to the students who had somehow got wind of this brilliant, charismatic professor who had been recently recruited by Blackett and who inhabited the Huxley Building. It was the basic reason why I chose to study theoretical physics at Imperial, under his tutelage. It was also the reason why hordes of Pakistani students flocked to Imperial College; indeed they represented a good third of the postgraduate intake. The early sixties were the days of spontaneous symmetry breaking, compositeness conditions, the gauge technique and of the birth of flavor SU(3). I vividly remember the verbal slanging matches between Salam and Ne'eman during the early exploration of the eight-fold way. You must realize that Salam was a formidable taskmaster and not many persons survived his scrutiny: he was ever impatient for quick progress and his fertile mind kept on exploring new avenues or angles – far too disconcerting for a budding postgraduate. Each day he would come into my room, rub his hands together and inquire if the problem was "all done", even though the calculations could be pretty gruesome. With Salam you either learned to swim well or else you sank: no snorkeling allowed. All things considered, I am really grateful to him for shaping my character and giving me experience in handling people, most of all Salam himself. When standing up to argue with him on one of the finer points of a problem, you had to be pretty darn sure of what you said because he had a wonderful intuition about the answer and was much more often right than wrong. When out of desperation you would confront him and ask him how he could be so certain, he would break into one of his wicked smiles, twiddle his thumbs, lean back in his chair, raise his finger and point upwards. Mind you, if you stood your ground and (on the odd occasion) turned out to be correct, he did respect you for it. On the other hand, Salam would not tolerate pedantry; he was often scathing of persons who did not measure up to his high standards, referring to them as "tom-tits" or "broken reeds"; those epithets were more derogatory than being labeled a "youth" or "young so and so".

Let me reminisce with you about the early days of the Centre. It started life in the top two floors of the social security building in Piazza Oberdan, as a few of you here will remember. It was, and still is, quite an imposing edifice, wonderfully located in the heart of town. Salam was determined that his vision of a successful center in theoretical physics would succeed and he devoted countless time and boundless energy to attaining that goal, ably aided and abetted by Paolo Budinich and Luciano Fonda. The first full year of operation, 1964, saw a

constant stream of visitors coming for workshops in many different fields, but principally in high energy physics. A few of the more permanent early residents were Fronsdaal, Barut, Oberman, Sagdeev, Giambiagi, Janouch, Werle, Niederle and last but not least my good mate John Strathdee. As well, Salam brought in a number of students from Imperial College, among them were Daniel Akyeampong, Jimmy Boyce and Ray Rivers. It is no reflection on Salam that he could be a bit irascible at times, for he was under great strain trying to keep the Centre financially buoyant and academically vibrant. He spent so much of his time coaxing or otherwise shaming the politicians into supporting the Centre, activities which distracted him from his true love, namely research. I remember one occasion, with some amusement, when all the delegates from various countries voted "yes" on some motion which affected the operations of the Centre; all except for Australia. This annoyed Salam intensely and ever after I detected traces of anti-Australianism. I said "with some amusement" because in today's climate the Australian Government is anxious to foster international links, so it would be a very different vote nowadays and Salam would have found other enemies.

The administrative staff which Salam had recruited from the IAEA included Moira Blessington, Jean Bouckley, Miriam Lewis and André Hamende. They provided every assistance to the scientists and even developed some of their quirks. I wonder how many of you recall the hilarious first of April pre-prints that Miriam Lewis used to issue, which contained the latest jargon. They are probably lodged in the archives. If any of you are feeling blue about the progress of your research, I recommend that you read them; they will clear up the cobwebs and put your efforts into perspective. ICTP was a cozy outfit those days and there was a tremendous esprit de corps, which no doubt still continues today, although ICTP is a much vaster entity. Salam's hyperactive life took him to all corners of the globe, mustering support for the Centre and generally showing the flag. It meant that he came only in short bursts to Trieste. Often the only times John Strathdee and I could discuss the finer points of relativistic $SU(6)$ with him would be an hour or so before or after his plane flight. The rumor that he did much of his research in transit or upon an aircraft is not particularly far-fetched. Because he was so often abroad, it was sometimes left for John and I to entertain the occasional visitor who came for brief spells to ICTP. I shall never forget the day that we took the venerable old scientist, Oskar Klein out to lunch on the Carso plateau; I only mention this fact because Klein, like Dirac, was a real hero in Salam's eyes and regarded by him as the real discoverer of $SU(3)$ flavor symmetry.

Salam was a model Director and took great pains in getting to know and welcoming anyone who worked in the Centre. He mucked in with everybody and lunch at the Mensa dei Ferrovieri near Piazza Oberdan was one of his favorite meeting spots. At weekends he loved going out for a meal of grilled fish at one of the numerous restaurants along the Strada Costiera. There was one in particular near Sistiana which caught his fancy – I don't know if that trattoria is still there?

Being impatient to get back to work, he had a mischievous way of gaining immediate attention from the waiters at the end of the meal if they delayed too long in writing out "*il conto*": he would just get up and leave! You should have seen the waiters scurrying to write out the meal ticket.

Anyhow, those first two or three years, until the success of the Centre was assured, placed a considerable toll on Salam's health and nerves. But in all that time his research activity remained feverish. I feel so honored to have had the opportunity to collaborate with him. Also, I owe him a great debt of gratitude, not only for offering me the job at ICTP but for conjuring a lecturing position for me at Imperial College in 1966, upon the death of my father, and with Paul Matthews' active connivance. We continued working happily together for many years until Tasmania beckoned me in 1976. To impress upon you his energy and vitality, there was one year (1968 as I recall) when he suddenly contracted appendicitis and went into hospital of course for surgery. At visiting hours, a mere two days after the operation, he was already talking animatedly about physics. This gives us another insight into his character: mentally, he felt anxious to keep abreast of progress and not miss anything of importance.

Salam remained in contact with me for a while after I emigrated and he always took genuine interest in my family, as he did with everyone whom he nurtured. He influenced my life at crucial stages in so many significant ways that I miss him greatly, as surely do the present company. I will always treasure my memories of his kindness, his sense of adventure and the fun of physics – who can ever forget his infectious laughter – his generosity, his friendship and his humanity.

69.11 "Fun with Abdus Salam" by Dr. Gordon Feldman, Johns Hopkins University, USA.

We have heard and will hear a lot about Abdus as a first-rate physicist, as a world-class leader, as a great mentor for many younger people and all of the other attributes that went into making him a unique individual – only one of a kind. I would like to talk to you more about the way I knew him as a fun loving, happy person who could always make the sun shine for the friends around him.

At the same time, being here in Trieste gives me the opportunity to remind many of you that the early seeds of the Trieste center were planted here in 1960 at a small intimate meeting held at Miramare Castle and organized by Professors Budinich and Villi. Abdus and I attended from Imperial College. We had a hilarious train ride from London to Trieste in which he presented himself as an Eastern potentate and I was his white factotum (always walking at least three paces behind him). I don't think we were very successful in the pretence.

Traveling third class could not have helped the image! And the meeting in Trieste was a joy. I would like to read a few lines from a small article in which we wrote about the meeting for *Physics Today*.

"In the letter of invitation the following appeared: 'The purpose of the Symposium is to satisfy a pressing need for continuous interchange of ideas on fundamental physics and to offer an ample opportunity for discussions. In keeping with its objective, the atmosphere of the Symposium will be very informal.' This purpose was admirably carried out. The writers have attended few conferences so enjoyable and at the same time so informative. The large international conferences somehow engender a type of 'conference tension', which was noticeably lacking at Trieste. Instead there was genuine relaxation, as well as good physics."

After describing the formal sessions we go on to say: "The informal sessions were held on the beach, at the table, and near the bar. The discussions were not always on physics. It is difficult to convey in a short article the impression this conference left on the conferees. Perhaps it is best described as one of pure delight."

And pure delight is what it was like being anywhere with Abdus.

I still remember the first occasion when I met him. It was in the summer of 1952 when he came to the University of Birmingham (then the domain of Rudolph Peierls) to work with Paul Matthews. I was Paul's graduate student. The sparkle in Abdus' eyes and the excitement he engendered were contagious. And he and Paul were a perfect match as collaborators and close friends, which they remained throughout their lives. For the next few years I would see Abdus again at Birmingham or at conferences, but it wasn't until after he and Paul moved to Imperial College in 1957 that our friendship grew. From 1959 to 1975 I spent every third year at Imperial on sabbatical or leave from Johns Hopkins. I was also there most of the summers in between. Those were happy times. I shared an office with Paul, and Abdus' office was either next to ours or just across the hall. Although I did collaborate on a couple of (forgettable) publications with him, most of our interactions involved just talking about physics and the world in general, usually in our offices or at lunch at Saroya's. The days were always enjoyable and full of laughter. Abdus, as most of you know, was constantly full of ideas and he was always bursting into our office to expound some new proposition or idea. Since I wasn't always receptive to them he dubbed me (affectionately I think) "the pissar". Of course there were so many of these ideas that, statistically, had some chance of being right. Both he and Paul loved to give names to expressions or equations (some of them a bit risqué) and then tried to get them past the editor when an article was submitted for publication. I remember when they submitted their paper on functional integration (where they nearly got the integration over Fermi fields right), Abdus was so pleased with what we now call the generating function – from which all other quantities, Green's functions, etc. follow – that they dubbed it something which I cannot

repeat at a public talk but which those of you who know your ribald poetry may recognize. However it did not get past the editor!

Abdus was not only excited about his own ideas but also excited when he read about something he had not known before and thought was simply beautiful. I remember his bursting into the office once and on the blackboard he drew a short line segment with two little circles attached to the end and with his eyes glowing with excitement he said "that's $SU(3)$ ". Needless to say, neither Paul nor I had a clue as to what he was talking about. Abdus had just started reading the works of Dynkin and although he couldn't answer any of our halting questions he knew the work was very significant and his joy was infectious. I could go on with many more such episodes which filled the days with joy, happiness and laughter.

Finally, in a change of pace, I would like to show you a copy of a newspaper article which Abdus sent me soon after my 1974-75 sabbatical at Imperial. It appeared in a Swedish newspaper just one day before the 1975 Nobel Prize in Physics was announced. Perhaps not everyone reads Swedish fluently so (with the help of a Danish colleague in Baltimore) I will translate the large print.

"A rapidly growing group of Swedish physicists appear to be moving towards the belief that the Pakistani born physicist Abdus Salam, for the time being active in Trieste and London, and his American colleague Steven Weinberg, and possibly others as well, will share a Nobel Prize in Physics. In which year such an award would occur naturally remains highly uncertain. One possibility is this coming Friday when the scientific academy will decide this year's Nobel Prizes in Physics and Chemistry."

For those of you who keep track of Nobel Prize winners, you may remember that in the year 1975 the Physics prize was awarded to A. Bohr, B. Mottelson and J. Rainwater.

There is also the first paragraph of the article which says: "Salam who is fifty, and Weinberg, forty-two, are both theoretical physicists, the former (Salam) is considered the modern day Einstein."

That to me is a fitting tribute to a great man and a great friend.

69.12 "What I Learned from Abdus Salam" by Dr. Gerhard Mack, Institute for Theoretical Physics, University of Hamburg, Germany.

This is a tribute to the significance of the work of Abdus Salam that, through the creation of this Centre, made it possible for people from so many countries to become friends. This is undoubtedly a very important achievement. [...]

When I was here in 1968 I never felt any pressure or any stress. I was a young man then and one of the kind who does not have his feet very firmly on the ground, I should say. Abdus Salam seemed to like me and anyway I got quite close to him during the time of our collaboration. I learned a lot from him about

physics and two main things in particular. The first was the importance of gauge theory. I think it is still more important than anybody thinks even now. He sent me to the library to learn about it, reading papers of Yang and Mills, of Higgs, of Kibble, and so on.

The second thing was on the use of mathematics. Now I think that this is a very good lesson also for today. Those who know string theory will understand what I mean. His message was that you should keep your attachment to mathematics to whatever is necessary for physics and if you had the right physics intuition then you could easily learn the mathematics that you needed. He told me with some glee that he didn't know any group theory but learned what he needed. When he was at Princeton and presented a talk on $U(12)$, Eugene Wigner asked him whether this was a compact or a non-compact group. His answer was more or less that he didn't care so long as he knew what the physics of it was. The lesson from this story was that you would find the right mathematics in due time when you encountered the proper physical difficulties.

But there were also many informal chats on various subjects. Among other things, he tried to put my feet a little more firmly on the ground by telling me of the money needed to run a physics center and how he went about getting it. I learned to know him as a very warm-hearted person when, unfortunately, my father had a bad accident in Germany and I had to leave; he sent me home right away.

The most important message and insight I got from him was one which some of us have mentioned before – of a political nature really. The essence of this message was that the people, especially the people of the developing countries, should be given a sense of dignity. This is, I think, the heritage which is important. Let me therefore say a few words of my own on that.

We all know how conflicts arise when people are deprived of the sense of their worth and dignity; how politicians use that in order to gain support by polarizing the society, making one part of the society look down upon the people in the other part. You can always find a difference and any kind of difference is transmuted into a difference of worth. Many of the worst things that have happened in this century have arisen in this way and the war in Bosnia is one of them. But we also know that the converse can happen. It grows out of hope. There was hope for some time. Let us hope that this is not going to be destroyed completely, that the conflict in the Middle East that seemed totally insoluble can be solved after all. The one real important reason behind this hope is that a sense of dignity has been given back to the Palestinian people.

The importance of the Centre did not concern the Third World only. There were also the people from Eastern Europe and since none of the speakers here today comes from the East, let me testify to that. In 1968, I met here in Trieste Ivan Todorov, from Bulgaria, and this started a collaboration of twenty-five years. When I met him, Ivan told me that this was his very first visit to the West.

He had been in Dubna for eleven years before this visit. Even after that, for many years, it was far easier for scientists from the Eastern countries, including Yugoslavia, to come here than to go anywhere else in the West. Therefore, I believe that Trieste has played an essential role in maintaining very strong and intensive personal relations between physicists of the West and their colleagues from the Socialist countries, even during the cold war. There was one exception however: I never met people here from the former German Democratic Republic.

I think that the heritage of Abdus Salam, the heritage of giving dignity to the people, should be kept up, and I am glad that the new director Professor Virasoro mentioned it in his speech. After the Nobel Prize was conferred upon him, Abdus Salam told me once: "I don't need this prize for myself, I need it for the people of the developing countries. I need it for doing something for them." This was in the eighties.

The last time I had a scientific discussion with him was when he was already very ill, a few months before the SalamFest, which took place here. We were standing in front of the elevator, certainly at least for ten or fifteen minutes. He told me of his interest in biology and we talked about physics. It was difficult to understand what he said. I had to get my ear close to his mouth. Nevertheless, he was still full of enthusiasm. This is how I remember him.

69.13 "Together in Lahore and Cambridge" by Dr. Ram Prakash Bambah, Professor Emeritus of Mathematics, Punjab University, Amritsar, India.

For a long time before the independence of India and Pakistan in 1947, Punjab University at Lahore had the responsibility for supervising and coordinating higher education in a large part of North-western India. This part consisted of the present Pakistan (minus the province of Sindh) and the Indian states of Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana and Union Territory of Chandigarh. Part of this responsibility was to hold the final school examination, called the MSLC or Matriculation and School Leaving Certificate examination. In the Spring of 1940, the results of the MSLC for that year were announced, and they carried the stunning report that a fourteen year old boy, from a remote place called Jhang, had not only topped in the examination, but he had also obtained a much larger score than all the previous ones. All earlier records had been broken by a great margin. The next day the regional leading newspaper *Tribune*, with which I now have the privilege of being associated as one of its trustees, carried the picture of a small boy with a large turban. The turban that you saw Salam wearing at the Nobel Prize ceremony is similar to the one he wore in March 1940. And that is the picture that I carry of Salam as I saw him for the first time.

With that kind of performance, he would normally have come to Government College, Lahore, for further studies. But due to lack of funds, or perhaps other reasons, he continued his studies at Jhang in a small college not known for its greatness. After two years he took the next university examination called the intermediate examination in the Faculty of Arts. He again got the top score.

In 1942, at the age of sixteen, he moved to Government College, Lahore. I had joined Government College in 1939 after my matriculation and at that time I was in the class one year senior to the class that Salam came to. That is where we first met in 1942. We were both sixteen. Government College was a leading institution in that area, but it was more of a public school than a university department, and it catered really to rich and influential people. They, however, took some good students and some sportsmen also to give it a certain character. The student body thus consisted of various groups of people with similar backgrounds. One such group was composed of those who had done well in examinations and Salam naturally found his place in this group.

This group had a subgroup including those who had topped in various examinations and Salam became a leading member of this subgroup. Soon after Salam joined us, one of us, Prem Luthar, got an attack of appendicitis and had to be rushed to the hospital. Salam looked up everything about appendicitis in the *Encyclopedia Britannica* and went to Prem's bedside to help nurse him. In the system, then and now, the hospital did rely on attention from friends and relatives to see people through their illness there. Salam spent forty-eight sleepless hours attending to Prem after his surgery. This endeared him to all of us and made him a very close member of the group. Also his laughter, such vigorous laughter in a small body, made sure that wherever Salam was, there was a lot of friendship.

The academic requirements were no strain on Salam, so he had plenty of free time. He discovered chess, which he started playing fairly well. He tried ping-pong, which he didn't play well. Then he started participating in debates, and spent more time in so-called frivolous activities than in study. I believe his father came to know of this and asked him to be careful so that his studies did not suffer.

Government College, Lahore, had no pretensions of great scholarship, but among the four teachers of mathematics there was a "strange" man called Chowla (whom perhaps many of you know as one of the great number theorists of present time), who was not only, perhaps, the only practicing mathematician in the region, but he did mathematics all the time and nothing else. The other teachers used to think he was crazy. He had the habit of ending his classes sometimes posing unsolved problems. So, while teaching cubic and quartic equations to Salam's class, he posed a problem of Ramanujan regarding four simultaneous equations in four variables. Salam spent three or four days on that, and then he came back to Professor Chowla with the solution that the four variables were the roots of a quartic whose coefficients could be found by solving a cubic. Professor Chowla sent Salam's solution to *Mathematics Student*

for publication. Thus, the first published paper of Salam appeared as a two-page note in volume 11 (1944) of *Mathematics Student*, pages 50-51. The note has at the end the name and address of the author as Abdus Salam, 4th year student, Government College, Lahore. He was an eighteen-year-old undergraduate at the time in an atmosphere where no one (other than Chowla, of course) thought of doing anything original. The last paragraph in the paper says: "By employing the same methods, we can solve the system of equations $x^2 = a+y$, $y^2 = a+z$, $z^2 = a+x$ much more rapidly than Ramanujan did. His is a very laborious method." One cannot but notice the confidence of an undergraduate student talking about an effort of the legendary Ramanujan. Unfortunately, I cannot show the paper here, but it can be seen in Salam's collected works.

In 1944, Salam took the B.A. examination with Mathematics, English and Urdu as his subjects. Once again, he broke all previous records by a large margin, actually more than five percent. He offered additional papers for an Honors degree in English and here again he created a new record, hurting the ego of some persons who, perhaps, played a somewhat negative role in Salam's career later, but I won't dwell on that. As a result of his performance in the B.A. in 1944, Salam faced a dilemma: should he go in for a Mathematics Master or should he opt for a Master's degree in English. He was equally good in both and had done extremely well. [...]

Salam opted for mathematics. I guess he felt that he could prepare English and History at the Indian Civil Service level on his own, but Mathematics would need more training. Since I was one year ahead of him as a student of Mathematics, we became closer still. In the meantime, I had also moved to the hostel, so we were neighbors. Neither of us could afford to buy books, so we borrowed them from the library on the clear understanding that each of us could walk into the other's room and take whatever he needed to study. We exchanged some notes sometimes, but since the system was no strain, neither needed the other's help academically. Salam's interest in literature continued and he had a great passion for the beauty of thought, expression and also human form. He discovered Oscar Wilde and for some time he was talking only of the beauty of Oscar Wilde's language and wit. At one time he was reading Lawrence's *Seven Pillars of Wisdom*, a few pages almost every day.

In 1946, he passed his M.A. examination, again standing first with a high score. And then the dilemma started. The Indian Civil Service examination allowed you to get in and help the community through the power that came that way. But the examination had been suspended in 1942 during the war and had not been restarted. Also, even if the examination had been restarted, Salam would have been too young to take the examination and he would have had to wait a couple of years before doing so. So, it was decided that he would spend a couple of years in England. [...]

At the beginning of 1948 he passed the Mathematical Tripos Part II with a first. It was rumored that he had the top score there also, though at Cambridge

they did not reveal individual scores. I came to Cambridge in 1948 as a research student and met Salam again. On his advice, with the help of Professor Mordell, my supervisor, I also transferred to St. John's from Fitzwilliams House where the Indian High Commission had placed me. In the Cambridge system, it was obligatory to have dinners in the college hall, and we had at least five dinners there every week. It was quite natural that Salam and I and a few others started taking dinners together because of our common background and language, and this group became very close. We used to walk together, go to movies together, and when we did not feel like working we went to each other's rooms and talked Punjabi till late hours. After having done Part II of the Mathematical Tripos in two years, Salam joined Natural Sciences Part II. He was miserable in the laboratory and when he took the examination in 1949 he was very apprehensive. But after seeing his result, he came to our rooms to give the good news that he had again got a first. He also described the following amusing incident. He said that after looking at his result at the Senate Hall, he met one of his lab supervisors, who said, "Salam, how did you do?" Salam said: "Sir, I have managed a first." The man turned a full circle on his feet and said: "This shows how wrong one can be."

Salam had now completed three years of his stay at Cambridge. He had a double first and his scholarship had come to an end. He was planning to go back home, take the Pakistan Civil Service examination and start playing his role as supporter of his family. Then, Fred Hoyle, I think, told him that the college would like him to stay for research and was willing to give him an extension for the purpose. [...]

He went back. With the help of Sir Zafrulla Khan, I think, he was appointed Professor of Mathematics at Government College, Lahore, given leave on full salary to be paid to his father, and sent back to Cambridge for work for his Ph.D. So he came back and persuaded Kemmer to supervise him. Kemmer told him that he would give him no problems and suggest no solutions, and the only thing that he could expect was that he could talk to him whenever he wanted to. [...]

I was going to Princeton in 1950 on the invitation of our old teacher, Professor S. Chowla, and Salam said: "If you meet Dyson, you tell him I have renormalized longitudinal photons." I happened to meet Dyson and mentioned this to him. He said: "I don't believe it, but if he has done it he will be very famous." And he is famous. On my telling Dyson that Salam had taken up this work because of his suggestion in one of his papers, Dyson said: "I had said it should be done, not that it could be done."

Salam was elected to a Fellowship of St. John's College, Cambridge in 1951 and I got elected in 1952. I came to Cambridge in 1954 for residence for a few months. During this time I again had an opportunity to spend a good deal of time with him, often enjoying the hospitality of his wife. Even then Salam had started thinking seriously of taking steps for the development of science in our countries. We both felt that one of the great difficulties for young scientists in our countries was isolation from active workers elsewhere. As we all know, Salam's

motivation for ICTP was to provide a place where young researchers from developing countries could interact with their peers and seniors and leaders of science from all over.

After 1954 we went our different ways. We met occasionally, for short periods, but whenever I met him he forgot his greatness, he forgot his achievements, and he reverted back to the old days talking about old friends and the times we had together. When my daughter, who is a mathematical physicist, met him at Trieste, he wrote in her autograph book some very flattering remarks about me. Out of her reverence for Salam, she is willing to consider that I am not entirely useless.

It was my great fortune to be associated with such a good human being who was one of the greatest contributions to mankind from our part of the world.

69.14 “Delight in Abdus Salam’s Company” by Dr. John Ziman, Professor Emeritus of Physics, University of Bristol, UK.

In 1954, I was in Oxford and just about to take a lectureship in Cambridge. John Spears, who was a theoretical physicist in Oxford, said to me: “Ah, you are going to Cambridge. You will meet Abdus Salam and you will know who he is by his conversation.” His conversation was like this: “Dispersion relations – oh, ho ho ha ha. Meson physics – Oh, ho ho ho, yes, ha ha.” So I went on a visit to Cambridge just before moving there, and as I was walking down King’s Parade I saw John Ward, whom some of you have heard of, who was with this man. He started his conversation and sure enough that was the way he talked. But his laughter wasn’t just about everyday things – you know that anybody might after all be rather cheerful outside his work. With him laughter was part of physics.

I have been reflecting upon the fact that when Professor Bertocchi and Professor Fonda referred to their readings from Salam’s books, they told me that what they read in those texts was as nothing to what they would have gotten from this laughter and from the delight that radiated around him in relation to the world of physics. They used the word “delight” and that is exactly the word I had written down myself while reminiscing on such a great person.

Before coming to the direct connections I had with him later, let me say something on an episode, which occurred in this building in the seventies when I was quite frequently in Trieste. As I was going into his office to discuss something, he was on the telephone talking to someone who had done an experiment that might or might not test the Salam-Weinberg weak interaction theory. It later occurred to me that he did not need the internet. Nowadays, everybody uses internet in order to have those continual conversations which probably distract everyone from doing his real theoretical physics. I am not sure how one does research when people are sending you messages. I would assume that one should better sit down quietly and get on with physics: this is how we

were taught to do it. But with Salam, it was on the telephone. He was already networking all through those days, building up his knowledge of physics, friendships, connections with people and carrying out this diffusion of the delight, the marvels, the beauties, the pressures of the great discipline in which we are engaged.

Now, let me turn to another side. I have to say that we were contemporaries, we were lecturers together in Cambridge from 1954 to 1957. I used to see him around there and we knew each other well at that time, but we were working in different fields and so there wasn't a very direct contact. In 1957, he went off to Imperial College and I went in due course to Bristol. And then in 1966, I got a message from him; would I come and drop in on him at Imperial College, he wanted to talk to me about something.

I have to say that at that time I knew that he had set up this international center at Trieste. What was it all about? Why did we need an International Centre for Theoretical Physics? Every good university was an international center for theoretical physics. And so on. I had my own views on the subject and was a little bit doubtful about the whole thing. [...]

I discovered in him what I hadn't suspected from this friend of mine, from this cheerful, brilliant, lovely man that we knew around. I discovered that he was essentially a man of power. That his charisma, his power, was not simply in relation to the physics he could do and the way he would help people and so on: it was a power to persuade. I don't know where it came from. It was an irresistible passion in him that created passion. This was perhaps because one always felt that what was to be done was something worthwhile in itself and not something that he just wanted to do. It was a cause, a true cause. And of course we have seen how that passion created this great place here and many other institutions around.

All these things that were created by him owe, I suppose, their being to this power to persuade. I saw this in action doing courses here, serving on the Scientific Council of the Centre, and all these experiences over the years. I have seen it being applied to the officials of the IAEA who were, I think, fairly a pushover. On the other hand, the Italian Government was a slightly more complicated business and they had to be persuaded. In fact, I am delighted to see Paolo Budinich here because Paolo had a completely different way of getting things done. The skillful, knowing, Italian way of doing it, this is quite different from the way of doing things by a Pakistani man of power. But somehow, between them they got things done.

There were moments actually when there were, at the Scientific Council, resolutions we had to pass, and we were told they had to pass and we never understood what they were, what they meant, but they meant another few hundred billion lire or so from the Italian government and therefore it was worth doing it. He applied this power to UNESCO and to all sorts of visiting people and got these things done.

I also feel, that this power was used more gently to the staff and I am glad to see Miriam Lewis here, but others who were the staff of the Centre, although they may have cursed him quite a lot of the time, knew that they were working for a great man and that he was behind them in their efforts. And this is what made this place a lovely place to be at because it was run very efficiently, everything worked and yet there it was totally unbureaucratic.

I have been asked to read the message from Stig Lundqvist, but before I do that, I have a question for those who knew Abdus Salam well. And my question is this: What exactly is ossobuco (bone marrow)? Whenever we went out to our local restaurant in Trieste, he always had ossobuco. I tried it. A very good, nice dish, but I was so fascinated by his particular love of that dish. I never actually discovered what precisely was in it. Perhaps that's more important than knowing how many quarks there are in a nucleus!

Now, I shall take over the final item of this morning's session which is the message from Professor Stig Lundqvist. I was asked to do this because Stig Lundqvist and I worked together for many, many years in the program of the Centre on condensed matter/solid state physics. I am deeply sad that his health prevents him from coming here. It doesn't say so in this letter but I know that it is so because he was deeply devoted to the Centre and to Salam. Altogether he is one of the most admirable and lovely people that gathered around in this Centre and my close and warm colleague for many years.

69.15 "Thirty Years of Condensed Matter Physics" by Dr. Stig Lundqvist, Professor Emeritus, Chalmers University of Technology, Gothenburg, Sweden. [Read by Dr. John Ziman]

I got to know Abdus Salam during my years in Uppsala in the fifties. As he was a scientific secretary of the big international conference to be held in Geneva on the peaceful uses of atomic energy, he became a very good friend of my teacher Ivar Waller, and Waller later became a summer guest at the Centre all the years up till his death at the age of ninety-two.

The Centre started with a small budget in 1964. The first years were mainly devoted to particle physics. After a few years, Abdus Salam's advisers recommended him to diversify and expand the program by including activities in condensed matter theory. The condensed matter activity set off in 1967 with a real bang. It started with a three-month course with a large number of key physicists lecturing. The Directors were J. Ziman, G. Cagliotti and F. Bassani. When Ziman left after a few weeks he entrusted the day-to-day running of the course to me, and since then I have been closely associated with the condensed matter program.

In 1970, the program was enlarged to include an annual three-month workshop in the summer and I was appointed the Director of that activity. I have had several wonderful collaborators in this project, such as Norman March, Paul Butcher, Elias Burstein and many others. This was in addition to an extended course on condensed matter physics, which was held every second year. Later in the seventies, Erio Tosatti became a professor at the International School for Advanced Studies (SISSA) of Trieste and a consultant for our program. We always had some small conference in the summer and he was very helpful in organizing these meetings and suggesting suitable topics.

All these years I had very close contact with Abdus Salam. We discussed the scientific program and above all the interesting new physics he was doing. The possibility of a Nobel Prize for him was coming close and as I was a member of the Nobel Committee, these discussions became very complex.

In the early eighties an important step was taken when Yu Lu was appointed to a leading permanent position at the Centre. He had done significant work as a leader and his initiatives have been instrumental for the development of the condensed matter group.

Around 1984, the ICTP got an unexpected major financial contribution. Instead of spreading the goodies thin over all the programs, I suggested to start a new series of conferences, which we call the Adriatico Research Conferences. They would be partly pedagogical and we decided to have long morning lectures, a total of twelve per conference, giving the major outline and presentation of the theme. The rest of it would cover mainly technical topics. The conferences were not restricted to condensed matter physics, but had a much wider scope. We have had up till now sixty-four Adriatico Research Conferences. Some of them have been centered on very tiny topics. As a whole, they have covered a very wide area. Abdus Salam gave us great support for this scheme.

This year we have been running the condensed matter program for thirty years. All this time Abdus Salam has been strongly supporting my activities and he has also been a close friend. He has given generous moral and financial support for our program. For me it has been a great experience to work with him and I wish to thank him for all his support and encouragement. I consider Abdus Salam as a very close friend and I sincerely miss him.

69.16 "A Lighthouse for Young Scientists" by Dr. Rexhep Meidani, President of Albania.

The foundation of the International Centre for Theoretical Physics, based on the ideas put forward by Salam, was a pioneering initiative to keep alive the higher education, the research and creative power of thousands of scientists, and many more in the future. It was a lighthouse for young scientists sending rays of light illuminating the dark paths of difficulties in the developing countries. The United Nations organization was established to promote peace in the world and

the International Centre for Theoretical Physics was founded as an instrument of this peace with a new visage, the visage of science. This investment and its benefits have always been visible and coherent.

And now after one third of a century from its birthday, we shall add to the initials ICTP – the symbol of wonder, spirit and cooperation of science – the name of one of the greatest personalities of the physics community, who devoted his life to keeping the morale of the poor scientists from developing countries alive and fought to prevent their pulling power from sinking to absolute zero. These new letters embody the name of the father of physics, who dedicated his energy to kindle the enthusiasm of young physicists, gathering them with celebrated peers from industrialized countries, respecting the principles of French illuminism: *liberté, égalité, fraternité*, organizing face-to-face communications between young and experienced generations, between fresh ideas and old ones, crazy concepts and standard ones.

I would like to emphasize that in my scientific career two moments stand out. The first relates to my post-graduate studies and research work at the Centre de études nucléaires at Saclay in France, which allowed me to collaborate with a team of superb French scientists, under the institution's spiritual leader, Nobel Laureate P.G. de Gennes. During this time I not only acquired valuable knowledge but I also developed warm and lasting friendships. The second is linked with my studies at ICTP, Trieste where I was fortunate to meet Professor Salam, a great and generous man. During the course of a decade it was always a real pleasure to work and stay at ICTP. It is no exaggeration if I define this Centre as a goodness of Salam. Invented by this special scientific, political and diplomatic brain it has served as a modern concentrated model of spiritual freedom, intellectual independence and real humanity, of scientific salvation and encouragement for poor countries, and a symbol of sociability for all physicists around the world.

Salam's target was not only to create a scientific center, but also to capture, through his human and spiritual imagination, the most advanced model of a community and a new building of collaboration, independent from race, religion, nationality or political affiliation, and moreover to light the path of an integrated peaceful world of free people with an open heart and original mind.

And I would like to believe, as Professor Salam did, that a new world will be possible through skillful advanced planning and real cooperation of scientists. Following Salam's ideas we must have the courage to think the unthinkable.

But, as elsewhere, to make the venture succeed, scientists will have to release, time after time, top-class or top-lab work and put in an enthusiastic showing also at political venues. There are good reasons for thinking that the intellectual and scientific brakes should be applied to proceed more cautiously when one deals with human demands associated with effective, integrated world governance.

In participating in the ceremony of unveiling the Centre's new name, The Abdus Salam International Centre for Theoretical Physics, I wish to salute the man who honored not only his country, not only the physics community but all the scientists in the world, by his example and by his ideal of a more fraternal society, based on the principles of justice and the dignity of human beings, that he embodied himself.

I am pretty sure that both his example and his ideal will continue to inspire not only his collaborators at the Centre, but all of us who share his belief that such a world is possible.

Better than anyone, Professor Salam understood what pragmatic policy and concrete diplomacy meant, and he applied them successfully. He was a real ambassador of physics in the political and economic communities, contributing everywhere to the financial survival of the Centre. He often said that scientific thinking helps society address its problems in a rational and systematic way. And I share the same belief that science helps people change their outlook on the social and economic problems they are facing. In essence, it is normal to think that scientific reasoning helps to find the important detail, the simplest one perhaps, in the complexity of questions, evidence and facts, to make predictions based on analyses and synthesis, on different levels of abstractions. Of course, the complexity of problems in social life or in the economic sphere cannot be explained by the so-called many-body theory and it is different from the scientific one, but the way of facing them and the methodology are the same. Also, there is no doubt that the scientific concepts are extremely useful in modern social and political life. Some days ago, at a meeting with local authorities in one district of Albania, I explained why a factory there was inefficient, based on the concept of critical mass for production. Analyzing this case and developing this idea more concretely, I pointed out by different examples that the concept of critical mass (related closely to the transition from quantitative to qualitative changes) is not only a scientific or philosophic concept, but also a political, parliamentary, economic, financial and social one, in a pluralistic system and a market economy.

Was not the concept of critical mass or critical size that was developed carefully by Salam quite important for the success of the physics community in any given country? It was this concept that generated the necessity of the foundation of the Centre.

It is true that politicians rarely choose physics as their major area of study, but Salam thought that science, and particularly physics, offers a kind of training that fits well with the intellectual and spiritual demands associated with effective governance. Considering this fact, I am sure that many scientists, responding to the conditions that their nations will face in the near future, will become actively involved in efforts to rebuild a new democratic world, their nation's democratic institutions as well as international equitable cooperation following the spirit and

the main human characteristics of scientific activities, which are concentrated in Rutherford's expression: "Science is international."

I would like to emphasize another important problem for scientific and technological development and for further human civilization, to which Salam made a great contribution; that is the support of basic scientific research.

Of course, efforts to obtain immediate concrete results through basic scientific research can often be a heart-breaking exercise with a lot of problems and difficulties. This is also nurtured by the pessimistic view that many of the world's problems – including problems in science – were brought about because people, particularly politicians and economists, considered or saw the immediate benefits or gains rather than the long-term problems. It may be that this is particularly true, but the history of science doesn't show that because, in general, a theoretical result of yesterday or today will be a fruitful application for tomorrow.

There are barriers, but through persistence and the tunnel effect the optimists of basic research will win one day, despite a few little headaches. Yet, given the level of intellectual capacity now found among the researchers both in industrialized and developing countries, I am certain, as Professor Salam was, that basic scientific research will play an important role, particularly in the long term. This role will find its expression not only in the acquisition of new knowledge but in the transfer of technology that will have a positive impact on the nations' social and economic well-being. To meet these challenges, the universities, or more specifically the departments of science in developing countries, will seek to increase cooperation with institutions in industrialized countries. Like here at the Centre, based on Salam's initiatives, a new policy has to be applied, pursuing joint conferences, seminars and courses to keep the researchers and students everywhere up-to-date on global scientific findings. To this end, new centers of cooperation or different organizations have to emerge and the concept of devolution has to be applied to generate new ways. Also, regional cooperation, in different fields, across old national borders (which sooner or later will evaporate as in Europe, as the European Union integration progresses) may in time engender a new set of collective organisms and mechanisms that weaken the pull of the old nation states. In this way, there is a chance to make some steps ahead towards the globalism of science, to enjoy other episodes of relatively rapid evolution, following closely that of the global economy. In this still imperfect world, where contacts count for so much, it is better and more fruitful to join in, rather than stand outside and wait for change.

Today, more than ever before, dedicating our sentiments to Professor Abdus Salam, I believe that each of us, as individuals, must not only struggle to make a better world, to build a new conscience, but also to make ourselves better and conscientious, for the important role to be played in our world. In this perspective, I think that we could at least feel and say that Professor Salam was for us, for our physics community, for science and all open-minded societies in

general, a chance of grasping and catching these problems at an early stage and of lighting our own path.

In unveiling the Centre's new name, The Abdus Salam International Centre for Theoretical Physics, my greetings are: "Many happy returns of this new birthday."

69.17 "We Shall Maintain the Level of Excellence of the Centre" by Dr. Gioacchino Fonti, Representative of the Italian Ministry of the University and Scientific Research and Technology. (Translated from the original version delivered in Italian.)

It is an absolute privilege and a true honor to pay, on behalf of the Italian Government and especially the Ministry of Research, our heartfelt and sincere respects to the memory of Abdus Salam. Being here today and participating in the ceremony not only respects the tribute rightfully deserved by a great international personality and, among other things, recipient of the Nobel Prize for Physics, but also means supporting and sharing an idea: that science is an irreplaceable instrument of peace, welfare and social growth throughout the world.

Conceived through the torment of his own personal experience which brought Abdus Salam to carry out his mission of research scholar outside his home country, the birth of the International Centre for Theoretical Physics constitutes a clear and concrete response to all those skeptics who deny science the power to overcome social, political and ideological barriers and to provide humanity with the key to progress and development. The Centre has hosted scientists coming from over one hundred and fifty Member States of the United Nations, the IAEA and UNESCO, for a total of sixty thousand visits.

The annual number of visitors, which in 1964 was merely 83, has reached about four thousand in the nineties. Around 53% of these visitors came from developing countries. The activities of the Centre are quite varied: from workshops to scientific conferences, from laboratory research to award presentations. Of particular importance is the Associate Scheme which allows high-level scientists who live and work in developing countries to remain in regular contact with the more modern aspects of their field of research. This is a program which helps to reduce brain drain in the Third World.

This brief overview of the Centre is sufficient to testify to the success of the institute which, moreover, has found its ideal location in Trieste. Trieste, meeting-point of western and eastern European, as well as of Mediterranean, cultures, is an appropriate location, therefore, for the rise of models of international cooperation in the field of science, whence the name "the city of science".

But this is not all. The example of Trieste did not fail to encourage also the creation of other centers elsewhere in the world, such as the Centro International

de Fisica, Santa Fe de Bogotá in Columbia, or the Pacific Center for Theoretical Physics in Korea, to name but a few. If all this, on one hand, brings us sadness since the person who started it all is no longer with us, on the other hand it comforts us when we look again at the ICTP. The Centre is alive and well in the scientific legacy, the commitment and the achievements left by Abdus Salam. We are certainly aware of the well-deserved reputation of the Centre throughout the world's scientific communities, and we pride ourselves in knowing that it has contributed to projecting an image of our country, which differs from that stereotyped by the mass media. Also worthy of consideration is the prominent role it has played as pioneer in the establishment of the so-called "Trieste system" within which such scientific enterprises as the International Centre for Genetic Engineering and Biotechnology (ICGEB), the International Centre for Science and High Technology (ICS), the International School for Advanced Studies (SISSA), the Research Area, and the Synchrotron Laboratory have been developed.

Consequently, I cannot but re-emphasize that it is a special honor for me to represent, on this occasion, the Ministry of Research, the governmental administration which, as a token of its institutional objectives in the coordination of research activity (including its international components) as indicated in the Ministry's statute, has assumed a role of tutelage for the Centre. This means that the Ministry's contribution to the Centre has but one objective: to guarantee the validity and the quality of scientific life and of the activities which take place here at the Centre, as well as elsewhere in the world in the name of the Centre.

As Government representatives, we are proud of having been able to support Abdus Salam at the right moment in the fulfillment of his dreams. And we, together with his successors, undertake to maintain the same level of excellence at the Centre, now named after him and therefore, a monument to his memory.

I shall conclude by conveying the greetings of the Minister of Scientific Research and Technology, Professor Berlinguer, with his best wishes for the continuing expansion and increasing success of the activities of the Centre.

69.18 "A Great International Servant" by Dr. Hans Blix, Director General, International Atomic Energy Agency, Vienna.

Abdus Salam appeared for the first time on the scene of the International Atomic Energy Agency as a Delegate from Pakistan at the IAEA's General Conference in 1960. Let me quote from the minutes, which I looked up a few days ago, of the 39th plenary meeting at the Neue Hofburg on September 22, 1960. Abdus said then, I quote from the minutes: "His delegation and others proposed that the Agency should sponsor an international institute of theoretical physics. Such an institute would need no laboratories or costly apparatus. A modest building containing lecture halls and a library would be sufficient. The staff would work on nuclear theory, the theory of elementary particles, reactor

theory and the theory of thermo-nuclear fusion. At first the institute would award about fifty fellowships a year, half to experienced physicists who would be granted one year's leave for the purpose by their respective institutes. A similar system, he said, had proved successful at the world famous institutes in Copenhagen and Princeton."

The proposal was moderate indeed and in line with the mandate of the IAEA, but it took some time to materialize. It was assessed by several committees and discussed at meetings of the Board of Governors of the IAEA, and of the General Conference as well. Eventually, it was decided to establish the International Centre for Theoretical Physics in Trieste, the seat selected among several other options, and it was officially inaugurated in 1964.

What Abdus Salam has left us is about ten times the size of his initial project. The "modest building", as he termed it, that he wanted is now a complex of four edifices and the fifty fellows have become some four thousand scientific visitors every year, and as I heard from the Italian representatives, about sixty thousand totally over the years.

Abdus used all his persuasiveness, which was not limited, his charm, and contacts which were also unlimited, to achieve these results. The Nobel Prize for Physics which he received in 1979 gave him a status that also helped him to achieve the expansion and which he used very much in order to get the expansion. Because of its instant success and a pressing demand, the Centre launched programs into new disciplines; mathematics in 1970, atomic molecular and laser physics in 1973, geophysics in 1975, and many others became regular features of the activities here.

The IAEA was responsible for the operation of the Centre from the outset. But from 1970 and onwards, UNESCO, which provided fellowships from the very beginning of the Centre, joined the IAEA in this responsibility. As the scientific programs of the ICTP came to cover much more than the fields which fell within the mandate of the IAEA, and as UNESCO has a broader mandate than we do, the administrative and financial responsibility was turned over to UNESCO in 1996.

However, I can assure you that the IAEA has continued to support the Centre, very much so, with money, particularly those programs which are relevant to its mandate. There are still courses run in cooperation with us – I saw one on the list for the coming year. Indeed at the IAEA we believe that the Centre has helped to strengthen also the image of the Agency as an organization, which although often operating in fields, which are highly politically charged, is engaged in and remains faithful to, and respectful of science.

During my sixteen years as Director General of the International Atomic Energy Agency, which will end next Friday, I have had many opportunities to meet Abdus Salam in Trieste and in Vienna and for admiring his brilliant intelligence, his innovative way of attacking problems, and his unyielding energy and impatience with red tape. Abdus had a passion for the progress of the less

privileged countries in the world. His constant message was that these countries must develop their own science and capacity in science. He himself helped greatly to achieve that. Let me also note that Abdus' thoughts did not focus only on equations and scientific formulas. He was also warmly a religious man with a strong sense of moral duty.

I want to use this occasion also to express the appreciation of the IAEA for the constant and generous support of the Italian government to the financial and other needs of the ICTP. And my thanks go as well to the authorities in Trieste for all their help and their generosity in providing the splendid buildings which constitute the "Campus of Miramare". Trieste and Italy were unique in offering, during the cold war, a serene oasis for East-West and North-South cooperation in science. Happily the cold war is over, but the oasis providing the clear stream of science is as needed as ever.

Abdus Salam is a great man of contemporary physics. He belongs to the history of Trieste and to the annals of the United Nations. With his passing away, a chapter of the Centre's history was closed and another opened with new challenges.

69.19 "Bridging the Gap Between North and South" by Dr. Adnan Badran, Deputy Director-General, UNESCO, Paris.

Professor Abdus Salam, the Nobel Laureate, was a humble natural scientist from a developing country who was passionately in love with the ideals and the vision of the United Nations for creating a better world based on justice, human rights and democracy by bringing together those who "have the knowledge" and those who "have not".

I came to know Professor Abdus Salam very closely in 1980 when I invited him to address the first graduation class of my University, in Jordan, and to receive an honorary doctorate. I remember Professor Salam's words in his address to the graduates: "The globe of ours is divided into two distinct human beings: one quarter of mankind who exploits 80% of the world's natural resources, while three quarters are still developing humans called 'Les Miserables' living on three fifths of the globe. What distinguishes one type from the other is not a genetic character – both stem from mother nature DNA – but they differ in their level of mastery of knowledge – science and technology – and its utilization for economic and social development."

Professor Salam had always been aware of the danger caused by the disparity between North and South and he knew that peace cannot flourish in our global village without analyzing the global crisis and the inequalities between the rich and the poor. Alleviation of poverty by deeds and not by words was continually in his mind to bridge the gap in humanity. The most important item on his agenda was capacity building in science and technology in the Third World that would allow to fill the breach in knowledge, to optimize international cooperation, to

eradicate illiteracy in science, to mobilize resources for fighting the marginalization of the scientists from the South and to bring the science of the Third World in the main stream.

To this end, he created the International Centre for Theoretical Physics (ICTP) as a model to bridge the gap in theoretical physics, applied mathematics and other fields of science between the North and the South; the Third World Network of Scientific Organizations (TWNISO), a network among centers of excellence in the South for overcoming seclusion and exclusions; and the Third World Academy of Sciences (TWAS), of which I am honored to be Secretary General.

Knowledge is what the inquisitive mind discovers at the laboratory bench or in the field. To disseminate knowledge is to empower the minds of men so that they can apply it to peaceful use. This is the real formula for human development and eventually the main component of the agenda of peace and development for the future of humanity. To alleviate poverty, it is essential to develop the indigenous capacity of the South so as to overcome disparity and conflicts between "infos" and "infos not". With knowledge, poverty will be mitigated, and peace will be achieved. Empowering people with frontier areas of knowledge through sharing and caring will create a harmonious world, where interdependence through international and multilateral cooperation become a mode of action for the development of world society based on justice, human rights and democracy.

"I had two passions in my life," said Abdus Salam, "one for the basic forces of matter at Imperial College, London, and the other for building a 'science transfer' to developing countries. I have been able to create at Trieste – under the auspices of the United Nations, the International Atomic Energy Agency (IAEA) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), and with the generous help of the Italian Government – a Centre (the ICTP) for thousands of young physicists and mathematicians who come every year from the Third World to interact and get trained in the North. It is crucial that developing countries invest in science for a brighter future to their societies."

Professor Abdus Salam described his schooling days in a typical Third World context as follows: "When I was at school in 1936 in Jhang in Pakistan, I remember the teacher giving us a lecture on basic forces in nature. He began with gravity. Of course, we all had heard of it in our town Jhang. Then he went on to say that there is a force called electricity but it does not live in our town; it lives in the capital city Lahore a hundred miles to the East. Then the teacher said: we just heard of a nuclear force but that only exists in Europe."

Once upon a time Professor Salam was a victim of this disparity. He then wrote: "When I returned home, I was the only theoretical physicist in the country, I had no one in my vicinity to talk to, to discuss or to share ideas with. The academic climate was not stimulating at all. After three years, I realized that staying any longer would not make sense. My work would deteriorate, the

harvest of achievements in physics would go to waste and I would be of no use to my country. I reluctantly decided to return to Cambridge." Professor Salam had come to realize the inevitable: scarcity of resources and isolation were the fundamental causes of the growing migration of scientists from the developing countries to the industrialized world.

He made the comparison of the scientific manpower and he noted in 1990: "There were 3,600 scientists/engineers per million population in the industrialized world. In Israel and Japan the figure was 5,500. But when we look at the Third World, there were only two hundred scientists/engineers per million population. So, the critical mass is lacking. Adult illiteracy is a major obstacle of scientific and technological development. There are 850 million illiterates in the world, most, if not all of them, in developing countries."

Nobel Laureates are produced in the laboratories of the West. Those from the Third World who succeeded have made it while working in the laboratories of the industrialized countries. Basic research and higher education have been established to generate knowledge and to train technologists to integrate knowledge from various disciplines in the development and use of complex technological systems and to identify practical problems, the solution to which requires more fundamental scientific understanding.

Out of the sixty-one million students in the world, 2% are in foreign countries. Of these, 70% come from developing countries. Sub-Sahara Africa provides the largest contingent (14%). Eighty percent of Ph.D. students from the Arab region study abroad in science and technology. The United States receive over one-third of all students studying abroad (1990) which amounts to nearly 3% of all students in the country. There is an even greater proportion of post-graduate students in the USA from abroad: 28% of all graduate science students and 47% of engineering students. Yet, few Americans study abroad – less than 25,000 (1990). In front of these figures, Professor Salam always maintained: "Brain drain can be converted to brain gain if the scientists of the Diaspora plant their roots in more fertile soils abroad while some of the branches shed their fruit in the mother land."

The passing away of Professor Salam will be profoundly felt by the whole scientific community, particularly those of the South. He strongly believed that science education lies at the heart of all development and unless the Third World builds its own capacity in science and technology, it will not be free. Therefore, science and mathematics education should be given priority for the individual training throughout schooling up to training in fundamental research.

To conclude, I wish to evoke Professor Salam's exemplary vision which is reflected in his own words: "Scientific thought is the common heritage of mankind."

69.20 "Uniting Third World Scientists and Their Organizations" by Dr. Mohamed H.A. Hassan, Executive Director, Third World Academy of Sciences (TWAS), Secretary General, Third World Network of Scientific Organizations (TWNISO).

Unify, unite, join, organize, network, mobilize – these are the words that characterized the life and work of Professor Abdus Salam, both as a physicist and a promoter of science and technology in the developing world.

The foundation of the Third World Academy of Sciences (TWAS) was a result of his intense passion to mobilize and unite the most distinguished scientists from the Third World for the purpose of promoting scientific excellence and utilizing it for the benefit of the South.

It all began in October 1981 when Salam was attending the general meeting of the Pontifical Academy of Sciences in Rome. He and eight Pontifical Academy members from developing countries discussed his proposal of establishing an academy involving the most distinguished leaders of science in the South. They all agreed on a joint memorandum and the dream was left to Salam to transform into reality. He first started by identifying the most eminent scientists from the Third World who had already attained international recognition and invited them to become Founding Members. In March 1983, I received a letter from Salam inviting me to spend six months at the ICTP to assist in various matters, including the organization of the foundation meeting of TWAS. Since then, I had the great honor, privilege and good fortune of being closely associated with Professor Salam for a period of over twelve years. Working with Professor Salam was a thrilling and fascinating experience. It was difficult to catch up with him at times, as he was constantly innovative; but always exciting, stimulating and educational and I cherished every moment of it.

The foundation meeting was successfully held in Trieste in November 1983 and Professor Salam was unanimously elected as Founding President of the Academy. The Founding Members were forty-one (including all the Nobel Laureates in science of Third World origin).

A generous grant of US\$ 1.5 million from the Italian Ministry of Foreign Affairs enabled Salam to organize a major conference in Trieste in 1985 to launch the Academy's programs. He invited the Secretary General of the United Nations to inaugurate the event in July 1985.

Within a short span of time, Professor Salam transformed TWAS into a world-wide premier organization that gives recognition to the outstanding achievements of Third World scientists, that supports and encourages the pursuit of scientific excellence in the South and that promotes South-South cooperation between individuals and centers of scientific excellence.

The next substantial step undertaken by Salam in his untiring efforts to improve the status of science and technology in the South was the establishment

in Trieste in 1988 of the Third World Network of Scientific Organizations (TWNISO). Through TWNISO, Salam united the leading scientific organizations in the South, including national academies, research councils and ministries responsible for science and technology. This ingenious initiative enabled TWAS to have a strong and effective political arm in developing countries and to address broader issues related to government funding for science and technology and science policy and management.

In conjunction with the 1988 TWNISO meeting, an important meeting of Third World women scientists was also organized by TWAS which led to the establishment of the Third World Organization for Women in Science (TWOWS). The President of this organization, Professor Lydia P. Makhubu, present here today, will tell you more about TWOWS later.

But it had always been the political will and political commitment by the leaders in the South to support science and technology that Professor Salam considered most crucial. He wrote in one of his articles: "It is a political decision on the part of those (principally from the South) who decide on the destiny of developing humanity if they will take steps to let 'Les Miserables' create, master and utilize modern science and technology."

In 1989, the former President of Tanzania, Dr. Julius Nyerere, invited Professor Salam to become a member of the South Commission which was established by the G-77 under his chairmanship. Although he was the only scientist in the Commission, Salam was able to get the message of science and technology included in almost every chapter of the celebrated Commission's report published in 1990. In a message sent to TWAS last year, President Nyerere wrote: "Abdus Salam was a very special human being, who combined a commitment to pushing forward the frontiers of science with a deep sense of responsibility to the countries and people of the developing countries. The South Commission Report would have been very different – and much less useful – without his contributions to the many discussions held and his constant reiteration of the importance of promoting the development of Science and Technology within developing countries."

In 1990, Salam became fascinated by the Consultative Group on International Agricultural Research (CGIAR) network of about sixteen international centers in agricultural sciences located in different countries in the South, and supported by the World Bank and a group of international funding organizations with an annual budget of about US\$ 300 million. He developed a project to set up a similar network of twenty international centers of excellence in various fields of applied science, technology and environment modeled on the ICTP. "If we can have such a network of international centers of excellence established in Third World countries, we will not only be able to stop the massive

exodus of scientific talent to the North but also link science and technology to production sectors," he said.

In 1991, I accompanied Professor Salam to the World Bank where he tried to "sell" his twenty centers project to the hard-line economists who, with their short-term adjustment policies, were hardly sympathetic to Professor Salam's long-term vision of science-led development. He was advised, however, by the Bank officials that he should seek the support of the heads of governments and ministers of finance in the South for this project. That prompted Salam to mobilize the political leadership in developing countries under "a commission of heads of state or government in the South" to support his project. The Commission (named COMSATS) was formed in 1992/93, and nineteen heads of state or government agreed to join it. Professor Salam invited the Prime Minister of Pakistan (his own country) to chair the Commission and organize its first meeting. The meeting was successfully held in 1994; but unfortunately, Salam was not well enough to travel to Islamabad to attend it. The meeting, however, paid a very special tribute to him and to what he had done for the Third World. It endorsed Professor Salam's project of twenty centers and agreed to establish the Commission's secretariat in Islamabad, with an initial endowment of US\$ one million donated by the government of Pakistan.

Salam's last endeavor before he became ill was to bring the economists and the ministers of finance and planning on board his science-driven development ship. "When it comes to the allocation of funds for science and technology, the ministers of finance and planning are most important, even more important than heads of government in many of our countries," he once said to me and his old friend Augustin Papic of Yugoslavia.

In April 1992, Professor Salam, Dr. Emmerij, the eminent economist and former president of the OECD Development Centre, and Ambassador Papic convened a meeting in Trieste involving a number of internationally renowned economists and an equal number of leading scientists to address what Salam called "the missing links between scientists and economists". In his opening speech he said: "During the course of our discussion on the issue, Papic and I asked the question of who were the enemies preventing the use of science and technology to achieve development in the South. We concluded that there were two of them. The first were the economists and the second were the scientists themselves, who were not their own friends. We blamed the economists and planners for not paying attention to long-term science-led development policies and we equally blamed the leading scientists for not trying hard enough to understand the economists and to get involved in solving practical problems. A new strong alliance between these two breeds is necessary," he concluded.

I just gave you a quick overview of the remarkable contributions made by this legendary figure, Abdus Salam, to the organization, development and utilization of science for the benefit of the Third World over a short period of ten years (1983-1992). The best tribute we can pay to his memory today, one year after his passing away, is to strive to fulfill the aims of the three monuments he

has bequeathed to us: ICTP, TWAS, and TWNSO, and to ensure that his tireless efforts of empowering the poor with knowledge, science and technology to enable them to overcome chronic developmental problems and further marginalization will be continued.

69.21 "Third World Women Scientists" by Dr. Lydia Makhubu, President, Third World Organization for Women in Science.

I had heard of Professor Abdus Salam long before the October 1988 Conference on the Role of Women in the Development of Science and Technology in the Third World which was convened in Trieste by the Canadian International Development Agency (CIDA) and the Third World Academy of Sciences (TWAS). This conference was a landmark event which was attended by some two hundred and fifty of the most outstanding women scientists of the Third World and by two women Nobel Laureates, Professor Dorothy Hodgkin and Professor Rita Levi-Montalcini from the North. It was at that meeting that I had the privilege and honor to meet and hear Professor Salam express in simple and even anecdotal but convincing language the idea of forming an association for Third World women scientists. He gave a brief account of the origin of the idea from Ronald Leger, then Director of the International NGO Division of CIDA, and how his idea was subsequently adopted at the TWAS bi-annual meeting in Beijing in 1987.

In his address, Professor Salam narrated his personal encounter and experience with the dilemma of women in science when his brilliant daughter, Dr. Aziza Rahman, obtained a Ph.D. degree in Biochemistry from the University of London and went on to do research at the Cancer Institute of Columbia University in New York. What began as a brilliant scientific career for Dr. Rahman was subsequently interrupted by marriage when she selected to raise her family rather than continue as a scientist. This, ladies and gentlemen, is a typical story for women in science and those in academia – women aspiring to intellectual leadership in the Third World and elsewhere in the world.

Ladies and gentlemen, I do not regard this typical story as a sad story, but rather as one which highlights the important role of women in human development, social stability and cohesion, without which societies would crumble.

In suggesting the formation of an association of women scientists in the Third World, Professor Salam and others like him were seeking ways of enabling women to accommodate their crucial social responsibilities without depriving humanity of what I believe is a unique contribution to science that only women can give. There have been diverse opinions regarding the potential contribution of women in giving direction and emphasis to the international scientific endeavor. Some have felt that male domination of science and technology has

resulted in the devotion of resources to scientific research related to military superiority rather than to areas such as the environment, food production, population and other spheres related to the improvement of the quality of life of the majority of people, especially in the Third World. They also have strongly posited that greater involvement of women would lead to enhanced emphasis on the use of science to address basic needs of humankind. Whatever position is expressed, there can be no doubt that humanity is poorer with the gross under-representation of women in scientific activities. That women constitute slightly over fifty percent of the human population is indicative of nature's balance which should be reflected in all human endeavors that affect all aspects of human life in a far reaching and fundamental manner.

The Third World Organization for Women in Science (TWOWS) was a product of these considerations. Its overall objective is to promote the participation of women in the scientific and technological development of their countries, with specific reference to linking high-level scientific activities to grassroots concerns.

Professor Abdus Salam was a Nobel Laureate in physics, an area in which women are often grossly under-represented. This did not deter his sharp mind from appreciating the need to help women transcend socio-cultural barriers and join the international scientific community. His support for TWOWS was clearly evident at its founding in 1989 and has remained steadfast over the years. TWAS has fully supported TWOWS, thus enabling it to run a credible program that has attracted the participation of women scientists from all parts of the world.

The women scientists of the Third World honor Abdus Salam's memory. We salute him for his foresight and dedication to the advancement of science and technology in the Third World and for his deep concern for their application and effective use in order to improve the quality of human life. His ideas on this subject will remain a crucial cornerstone in all endeavors by women scientists to participate fully in the advancement of science and, more so, in those scientific pursuits which aim at improving the lot of humankind.

69.22 "Abdus Salam's Cosmic Anger" by Nigel Calder, Science Writer, UK.

In my many encounters with Abdus Salam as a science writer, I remember him as a patient teacher of stupid journalists. I recall that at Geneva in 1958 he took time off from a busy United Nations conference to explain parity violation to me, over a cup of coffee. At a more critical time, in 1976, I was doing a big program about particle physics for the BBC and other broadcasters, and I was in a fix. I had sold this idea to the broadcasters and I didn't understand the subject.

A science writer cannot explain science to the general public unless he or she grasps the concepts fairly deeply.

Fortunately Salam was in London; unfortunately he was extremely busy. "I can have a quick lunch with you," he said. So in the senior common room at Imperial College I tried to extract from him an understanding of what we now call the electro-weak force. Over coffee, we still were not getting very far, and Salam went to make a phone call. He came back and said: "Now I have some more time."

We went round the course again and again. It was about half past three in the afternoon and I wasn't getting there, although I desperately needed to understand. I have a vivid memory of saying to him: "Yes, you say that a photon can turn into an electron and a positron ..." and he said: "No! I say a photon IS an electron and a positron." At that moment the scales dropped from my eyes and at last I understood what he was driving at.

We have heard many key words today about Salam: about his laughter, and the delight that surrounded him, about his generosity, about his passion and his power. I want to offer you another word which goes deep, I think, into his personality, and that is his anger.

I often saw him angry. I don't mean in a petty sense of getting cross with somebody who had annoyed him. I mean a sort of cosmic anger. He was, for example, deeply proud of medieval Islamic science, but angry about the way it had declined, and about how difficult it was to revive. He had a special anger for world poverty. He would put down a newspaper and almost shout at me about the wickedness of the terms of trade that were turning adversely against the Third World, and were thereby wiping out everything that was being given by way of aid and technical assistance.

Salam knew that it was an accident of history that, in the 17th century, the scientific revolution occurred in Europe. And in the 18th century the industrial revolution also took place in Europe, with the consequent division of the world into two. In 1991, Salam said at a conference of the International Council of Scientific Unions: "I have long maintained that this globe of ours is inhabited by two distinct species of human beings; the developed and the developing, the rich and the poor. What distinguishes one type of human from the other is the ambition, the power, the élan, which basically stems from their differing mastery and utilization of present day science and technology."

He often said: "We know the world has enough resources, technical, scientific and material, to eliminate poverty, disease and death for the whole human race." In 1964, when I was editing *New Scientists*, I invited one hundred leading scientists and scholars from around the world to cast their minds twenty years forward. Was science leading us towards heaven or hell? One of the very first replies that I published was from Salam, and he took a rather pessimistic view. He thought that the big divide that he saw would continue, as indeed it did.

He also wrote this: "Never in the history of mankind has a change happened all at once. The one great change of the first half of the century, the passing of the colonial age, was the culmination of fifty years of crusading. In most places it started with a few men whose passionate fury first overwhelmed their own peoples and then succeeded in rousing the liberal conscience of their captors, bringing home to them also the utter economic futility of holding down an unwilling people. This is the normal process of change."

Salam continued: "What makes me worried is that no such thing has yet happened in the underdeveloped world as far as the harder crusade against poverty is concerned. And in the few places where realization has come, it has not been purposeful enough yet to bring down the internal social and organizational barriers, nor to be able to defy external pressures. In the next twenty years I trust this crusade will come to be preached with the fury it deserves."

You will understand from his prose why he was torn at one time between following a career in science or a career in English. And Salam's sense of history gave him his cosmic patience, in contrast with his superficial impatience in everyday matters.

How can we express his fury about the division of the world in a modern, practical fashion? All of us in this room know what he did. We are celebrating him and we know his spirit lives. Among physicists world-wide, his memory is well preserved; also in Pakistan where so many turned out for his funeral. But amid our euphoria, and our happiness in remembering his achievements, don't forget this. If you asked an ordinary person in the street, in London, or Berlin, or San Francisco, or Rio de Janeiro, or Accra, or Jakarta, "Who was Abdus Salam?" they wouldn't know.

What can we do about that? Salam was a romantic and I am a romantic. I believe that human beings by taking thought can change the world. Let me mention another romantic story. Marie Curie came from Poland, which was not renowned for its science at the time. She became a world-famous scientist and won the Nobel Prize earlier in this century. I am sure that Lydia Makhubu will agree that the example of Marie Curie was an inspiration to young women in many countries to dare to become scientists in a male-dominated profession; Dorothy Hodgkin, for example, was mentioned.

That leads me towards my main point. Professor Bambah and Professor Durrani have spoken of the childhood and adolescence of Salam in Jhang and Lahore. Professor Badran told of the amazement that someone from the Third World should win the Nobel Prize in physics. Here is a wonderfully romantic story of a young lad in a turban from a market town in the Punjab, that nobody had ever heard of, who became a leader of physics and faced up to politicians as a champion of the world's poor. He wore the same kind of turban as he had worn as a child, to collect his Nobel Prize from the King of Sweden.

The thought I want to leave you with is that his story should be told to every child in the Third World. As a professional communicator I don't know what the ideal means would be. Perhaps a book in strip-cartoon format which could be translated into many languages, perhaps a film or a video. But the story will inspire young people with the idea that, wherever they come from in the world, they too can make careers in science – or indeed in any other profession at present dominated by the rich countries.

69.23 “Salam as I Knew Him” by Munir Ahmad Khan, Former Chairman, Pakistan Atomic Energy Commission, Islamabad.

It is a matter of great honor for me to be invited this afternoon to join in paying a tribute to Professor Abdus Salam both as a Pakistani and a friend of Salam. I feel proud and grateful that you have decided to rename the Centre as a living monument to his memory. While the Centre was conceived by Salam it would not have succeeded without the generous and continuing support of the Italian government, the International Atomic Energy Agency, United Nations Educational Scientific and Cultural Organization, and the collaboration of the Physics community and friends around the world. They all deserve our sincere gratitude.

We have already heard about his remarkable achievements. He was a monumental figure of our time who operated at the world stage in different roles. He was not only a scientist but a visionary who conceived and built great institutions and temples of science; a patriot who served his country well; a servant of the Third World who infused a spirit of confidence and hope among the scientists of the developing countries; and above all a true cosmopolitan who brought North and South and East and West closer together. So many around the world owe so much to him that we cannot repay our debt to him. I shall not repeat what my distinguished friends have already said before but I shall touch upon a few aspects of his life that I knew something about.

I met Salam as a contemporary at the Government College, Lahore, in 1942. I could have met him four years earlier in the Central Model School, Lahore. However, after having been selected for admission, the headmaster quietly advised his father to take him back to Jhang because the boy was wearing a red Fez cap and the other students might make fun of him. It was an advice, which the headmaster lived to regret. He was already a legend for his academic achievements when he came to the Government College, Lahore. We fought the College Union elections together in 1945 but he won as President and I lost as Secretary. He also became the Editor-in-Chief of the College magazine. He was a rare combination of literary and scientific talents.

It seemed that fate was guiding his career for he nearly got derailed on many occasions. Having stood first in English and Mathematics his tutor wanted him to

become an English teacher. But I suspect he felt that he could play chess better by sticking to Mathematics. In those days of the British Raj the highest aspiration of a young man was to become a civil servant in His Majesty's Service. He nearly got into the Indian State Railways but fortunately failed the medical test. The fact that he wore spectacles from an early age also saved him from becoming an engineer and saved the Railways because he was no mechanical genius. His father wanted him to join the famous Indian Civil Service. In 1946, he was one year too young to compete. His admission into Cambridge was also a happy accident. His father who was a senior clerk in the education department in Jhang was too poor to send him abroad but Salam won the "Peasants Scholarship" and his admission at Cambridge took place at the last minute because of an unexpected vacancy at St. John's College under Professor Paul Dirac. He sailed for Cambridge from Bombay in September 1946 after escaping arrest as a suspected deserter from the Navy even though he had never seen the ocean before. The ship, which carried him had six hundred Italian prisoners of war going back home. This perhaps accounts for his affinity for Italy and its cuisine. When he landed at Liverpool on a cold morning he was shivering. Sir Zafarulla Khan, his mentor, was there to rescue him and lent him an overcoat. In those days, Cambridge had no central heating and he acquired the habit of being overdressed all the time. This explains why we often saw him wearing a topcoat even in the summer because he was perpetually cold.

For a boy from Jhang who had not seen electricity until his teen years, Cambridge demanded great adjustment. He did it by wrestling day and night with mathematical problems. He finished his Tripos in two instead of three years. Professor Fred Hoyle advised him to spend a year at Cavendish Lab to do some experimental physics. But he had no patience for labwork as his hands could not keep up with his imagination. After graduating he made a brief trip to Pakistan and got his "Peasant Scholarship" renewed at Cambridge.

While doing his Ph.D. another happy accident occurred. When he was challenged to solve an intractable problem within one year, which had defied such great minds as Dirac and Feynman, he found a solution for renormalization of Meson Theory within six months. From then on he caught the fancy of such great men as Dirac, Bethe and Oppenheimer. Upon his return to Pakistan as a famous scientist he was rewarded by being made Head of the Mathematics Department at the Government College and President of the Football Club at the same time. He soon found that the two did not mix well and the situation was unmanageable for him. He felt cut off from the mainstream of international physics and this "forced" isolation choked his genius. Although he loved Pakistan he could not live a life of physics there. This inner struggle left a deep imprint on him. Later on in his life he could relate himself fully to the anguish of isolation, which stifled the flowering of many gifted scientists of the Third World who could not grow because they were unable to interact freely with active research centers and felt left out. He became more troubled after the communal disturbances in Lahore in 1953 in which his religious community was targeted.

Under those circumstances he felt he could not resist an offer of being a lecturer at Cambridge. Although he left his homeland for good in 1954, his heart always belonged to Pakistan.

Salam and I were out of touch between 1951 and 1958 when I was in the United States. But we resumed our association when I joined the International Atomic Energy Agency in 1958. We found we had many things in common. But unlike him my first love was not Theoretical Physics or even Mathematics. He regarded nuclear fission and nuclear power as passé. However, we had a common interest in the development of Science and Technology in Pakistan and the Third World. Also, he wanted someone to talk to in Punjabi to share his vision of a grand design to rescue science in the developing world; his hopes and fears and his disappointments and frustrations at not being appreciated at home and even rejected by those he loved most.

One morning in September 1960 he came to my office in Vienna lamenting the fact that the Agency was not doing enough for the developing countries. He said he had a wonderful idea to set up a Centre for Theoretical Physics under the IAEA. It would cost very little – just pencil and paper but could be a meeting place for the East and the West and help break the isolation of physicists in the developing countries. He wanted to see someone in the Agency to push this idea further. I called up Prof. Seligman, Head of the Research Department in the Agency and he asked me, “Who is Professor Salam?” When I told him that Salam was the youngest Fellow of the Royal Society and a Professor at the Imperial College his tune changed. Later, Salam and Seligman became good friends but poor Seligman could not live down his faux pas for the next thirty years. Salam made his proposal for the establishment of the Centre of Theoretical Physics before the General Conference but met with strong resistance from the advanced countries. The Agency’s Scientific Advisory Committee, which included Nobel laureates like Rabi, unanimously opposed the idea. But Salam was not willing to give up. He marshaled the support of the leading theoretical physicists from all over the world. Dr. Eklund, Director General of the Agency, supported him. Finally, the Board of Governors and the General Conference overruled the Scientific Advisory Committee. That is how ICTP came into being.

I remember the day he came to Vienna to plead for his Centre before the Board. He landed at the airport dressed in his topcoat and a canvas hat which was not only discolored but rumpled out of shape. I was horrified to see him in that attire. I persuaded him to take his coat and hat off which I deposited in the trunk of the car. Between the airport and the Bristol Hotel I managed to make the hat disappear. When he reached his hotel room he started looking for his hat. I carried out what appeared to be a strenuous search. Then I reminded him that he had to rush to the Board meeting and the search for the hat could be resumed later on. He accepted the logic of my suggestion. He was very eloquent before

the Board. At the end of the debate Prof. Smythe of Princeton University, who was on the Governing Board, remarked: "A large number of member states support the ICTP. So does Prof. Salam – and he is equal to several member states." There was laughter. The issue was clinched and the Centre formally approved in 1964.

Salam was a deeply religious man who saw no contradiction between science and religion. He believed that the pursuit of knowledge was a form of prayer, and God enjoined upon His followers to seek knowledge and discover the secrets of Creation. Only one spirit permeated the entire Universe and held it together and all forces emanated from the same source. That underlined his faith in the eventual unification of all forces. But he believed that science should not be pursued for the sake of science alone. It had to be put to use in the service of man, which represented the highest creation of God. He wanted to employ scientific knowledge for the uplift of humanity and for accelerating the economic and social development of the Third World. This explains why he expanded the role of the ICTP from theoretical physics to cover many applied fields as computers, electronics, chemistry, energy, environment, biotechnology and so on. Today Trieste is fast becoming a Science City with numerous Institutes, which have sprung up around ICTP.

Salam was not only a servant of science but a servant of the Third World. He awakened the developing countries to the crucial role that science had to play in their development and survival. He fired the imagination of many Presidents and Heads of Government and policy makers throughout the world to build scientific institutions. But his greatest legacy is the brainpower that he developed. Thousands of scientists from the Third World have come to ICTP to be inspired by his vision and go back charged with zeal and enthusiasm to light the torch of knowledge in their respective countries. As C.P. Snow said: "Few have done more for the talented poor and underprivileged of the Third world than Salam." In the difficult years of the Cold War he brought together the physicists from the East and the West to build a bridge of science, which served the world so well.

Though Salam lived abroad, he rendered invaluable services to Pakistan in the development of science and technology and remained as the Chief Scientific Advisor to the President and a member of the Pakistan Atomic Energy Commission for fourteen years. He guided us in building our atomic energy program from its very inception and helped in the setting up of the first research reactor and acquisition of the nuclear power plant at Karachi. He encouraged the Government to train scientists abroad, many of whom are present here as leaders of Science in Pakistan. He was responsible for initiating our space research program. He obtained help from abroad to solve water-logging and salinity problems in the country. He prepared a master plan for the promotion of science and technology. He gave us the idea of starting the Nathiagali College on Physics

and Contemporary Needs, which has held meetings over the last twenty-five years. He very much wanted that we should establish a Centre for Physics in Pakistan, which would work closely with the ICTP. I hope we will translate his dream into reality in the future. For us, Salam was an inspiration and a window to the world of science, which we have lost with his departure.

I had the privilege of hosting Salam's visits to Pakistan over a period of about fifteen years, which included calls on our Presidents and Prime Ministers where he pleaded the cause of Science. His ultimate desire was to retire in Pakistan and help build a new generation of young physicists in the universities. He remained a Pakistani until the very end. When he went to receive the Nobel Prize in Stockholm he made sure that he was dressed in his native costume including the golden 'khusa' shoes and a village turban. Incidentally, he had forgotten how to tie his turban. The curious work of art reflected in his headgear at the Nobel ceremony was the creation of the cook of the Ambassador. But he wanted to underline the fact that he had not forgotten his roots and was proud of his rural background of a backward town of a developing country.

My last detailed meeting with Salam was in 1992 at Trieste. His health had started to fail. I remember that he insisted on climbing the stairs to his villa unaided. The following day he made breakfast for me, which we ate in the kitchen while he talked about the future. He said he was working on applying the principles of physics and mathematics to biology for explaining the structure of a molecule. He was not satisfied with unifying two of the four elementary forces. He was developing a new hypothesis about the origins of homochirality of life on Earth. If he had lived longer he would have contributed more to our knowledge about the origin of life and how its character was determined by interaction of weak forces, which violate parity.

I saw him only three months before his death at his residence in Oxford. I told him how we had celebrated his 70th birthday in January 1996 and the tributes, which were paid to him throughout Pakistan. He listened to me but did not respond. He just stared at me as if he had risen above praise. As I departed he pressed my hand feebly as if to ask me to convey his thanks to all those who had said kind words about him.

People often ask me, "Will Pakistan produce another Salam?" I do not know whether this will happen or not but one thing I am sure about: From among the thousands of young scientists whom he had inspired through their visits to Trieste and by his exhortations around the world there will be many who will follow his path. I believe that in the next century some new Nobel laureates will come from the Third World as disciples of Salam.

Salam was a colorful and complex man with many personalities in one. He had many pursuits, passions, and interests. He was both a visionary and a builder. His life's work can be summed up in one couplet of the Poet of the East Muhammad Iqbal who said:

Your world is not the world
of bricks and stones you see around,
Your world is the one
which you create yourself.

Professor Salam certainly created a world of his own full of cities of science with citadels of learning where thousands of devotees come year after year to discover the secrets of Nature. This Abdus Salam ICTP is but one manifestation of the New World, which Salam created.

69.24 "Servant of Peace" by Dr. Asghar Qadir, Quaid-i-Azam University, Islamabad, Pakistan.

Abdus Salam – Servant of Peace. That was his name and that was his life. He dedicated it to the improvement of the Third World. His vision – a new paradigm for development – that science and its concomitant technology will alleviate the lot of the under-privileged nations by allowing them to leap-frog straight from the nineteenth to the twenty-first century. Not that he was a dreamer who expected there to be development without competition. He realized the importance of competition in pushing development forward at a more rapid pace. He encouraged competition – not in the sense of conflict, but in the context of cooperation. To him evil flourished through ignorance and was to be fought to the bitter end by knowledge. Science was to dispel this evil from the world. To him the development of science was a responsibility of the whole world, not only of the Third World. According to him, we were not pulling our load. He took on the responsibility of trying to help the Third World to struggle out of the darkness of ignorance and shed the light of science to dispel its problems.

Salam knew that he could not achieve his goal alone. He was perfectly ready to commandeer any and all people he could, to help him in his mission. He knew whom to request, whom to flatter into helping, whom to coax and cajole, whom to order and whom (like me) he could bully and brow-beat into doing what was needed. He demanded the impossible from his helpers in the enterprise of developing science in the Third World, but invariably still more from himself. His successes, like the Centre, are truly amazing, but he remained dissatisfied. There was always more to be done. His focus was not on what he had achieved, but on what remained to be done. I remember telling him very proudly of the development of my Department and his immediate response to that: "But what are you doing for the rest of the country?" He realized that there can be no stable equilibrium in development. If one does not go up one must come down. Now

that he is no more, I myself can feel his sense of urgency about getting things done.

Though Salam's vision was for the Third World in general, he had a special soft corner for the Islamic World – and within that most of all for his homeland, Pakistan. He did what he could to motivate us Pakistanis to work for scientific development in Pakistan. I met him for the first time in 1964, when I went to the Physics Department of the Imperial College of Science and Technology (as it was then called) as an undergraduate freshman, and my career was greatly influenced by him and his advice. He was aware of the major problem of isolation faced by scientists in the Third World, and the enormous paucity of manpower there. He regarded it as imperative that Third World scientists diversify and cover more than one field, so as to reduce the problems of manpower shortage and isolation. This led to my pursuing research in physics, mathematics and economics, and in various areas in each of them. When I came to the ICTP for the first time in 1972 as a nearly fresh Ph.D. and a new faculty member at the Islamabad University (as it was then called), he told me that it was my duty to see to it that other Pakistanis could benefit from it. I felt that it was unfair of him to ask that of me. How could someone so junior as I manage to make much of a difference? Following the usual plea of people in Pakistan, I said that he did not know how difficult it was to get anything done there, particularly for a non-entity like me. His answer was typical: "Do you think it was easy to build this Centre? Where do you think the money to run it comes from? Do you suppose it runs itself?" When I thought about it, I could see that it must have been well nigh impossible to convince the developed countries to support the Third World in developing basic science at the frontiers. It would be nearly as difficult to keep flowing the funds that enabled us to benefit from it. We did indeed have a responsibility to him to ensure adequate utilization of the Centre to provide him with the basis to continue to extract support from elsewhere. I still felt that too much was being asked of a mere non-entity like me. Of course, Salam did not leave me to manage it all on my own. He provided the support to make me less of a non-entity. I later went on to work actively for proper participation in ICTP activities by Pakistani scientists. From there, it was a short step to getting involved with working for the development of science in Pakistan (to what extent I could).

When he received the Nobel Prize in 1979, he felt that he had won it, not for himself, but for the Third World. As such, he felt that he had no right to use the prize money for personal purposes but that it must be used to further his mission of development of science in the Third World. He especially put aside money to help Pakistan and Pakistani students. In 1980, he asked Professor Fayyazuddin, with my assistance, to formulate the rules and procedures for a prize to be awarded to young Pakistani scientists for their research in the basic sciences. Our suggestion was that the prize should be awarded annually by rotation for physics, chemistry, mathematics and biology to Pakistani nationals, normally resident in

Pakistan, below thirty-five years of age on December 31st of the year for which the prize was to be awarded. It was to consist of a certificate giving a citation and a cash award of US \$1,000. It was to be awarded on the basis of the collected research and/or a technical essay written especially for the prize. (My idea, in making the latter provision, was to allow for something like the Adams Prize as well.) To manage the prize a committee was proposed, consisting of the two of us and Professor Riazuddin. This proposal was approved by Professor Salam. Unfortunately, Riaz and Fayyaz both left the country and I was left to manage it on my own. I took to myself the title of Secretary of the Salam Prize Committee and proceeded to "manage" it. The first prize was for physics for the year 1981. It was to be awarded at the end of the year and fortunately Professor Salam himself was available to present the prize to the winner. I had dubbed the prize "The Abdus Salam Prize for Young Pakistani Scientists". As could have been anticipated, Professor Salam protested against the name for the prize. (This was at the ceremony to award the prize.) I was prepared for that, and put it to him that it enhanced the value of the prize to be associated with his name. The matter was put to the house, which gave overwhelming support for my name for it. As such it acquired that name then and has retained it since.

The Salam Prize has acquired a very high reputation. We have had some very notable winners. Among them is one of the speakers at this meeting today, Professor Pervez Amirali Hoodbhoy of the Department of Physics, Quaid-i-Azam University. There is Professor Suhail Zuberi (for his work in quantum optics), Chairman of the Department of Electronics, Quaid-i-Azam University, and the recent prize winner in Mathematics, Dr. Naseer Shahzad, who shows immense promise. There have been many other Salam Prize winners who have also demonstrated their worth since receiving the prize. In fact, the prize acquired an international reputation and has been emulated outside Pakistan. I remember Professor Salam telling me about it one day with great pleasure. His appreciation of my efforts displayed at the time will always be one of my most cherished memories.

Professor Gordon Feldman mentioned that some time before he received the Nobel Prize Salam had been referred to as "the next Einstein". This was not an exaggeration. A scientist does not enter that special category to which Einstein belonged just on account of his contributions to his special field, but because he has had a greater impact – he has become a household word for people outside his own field. Of course, he must have made a major impact in his own field. No one can doubt that in Salam's case. We have been hearing of the many contributions he has made to high energy physics. They started with his work on renormalization. Then he missed getting the Nobel Prize for his idea of parity non-conservation. He went on to the pioneering work on SU(3) for which he could easily have got the Nobel Prize. Though his early attempt at unification of internal and external symmetries SU(6,6) was not successful, it led to the idea of supersymmetry, which is one of the main driving ideas of modern high energy

physics. After Wess and Zumino presented their paper on supersymmetry, he and Strathdee wrote it in more easily usable terms. Many workers continue to use the formalism set up by Salam and Strathdee. His work on electroweak unification needs no comments. However, it is worth pointing out that the first published idea of Grand Unification is in the paper of Pati and Salam in 1972, as is the original suggestion of proton decay. Regardless of the outcome of the suggestions, it cannot be denied that these ideas have guided the development of high energy physics in recent times. In fact, I remember a talk by him on the morning of January 29, 1971, just before my Ph.D. viva voce examination in the afternoon, in which he mentioned the hope of unifying the strong with the weak and electromagnetic forces and finally incorporating gravity. Though he was thinking of $SU(3)$ flavor instead of color, the basic idea was already there at that time, and has driven developments in fundamental physics ever since. All this, however, would not have made his name a household word. The impact of Einstein was felt through the philosophical implications of his work, and was later felt at Hiroshima and Nagasaki. That is not the impact of the Servant of Peace. Due to him, any number of scientists have been able to continue to work in the Third World and to maintain their contact with the latest developments in science. This has enabled those countries to bring up a new generation of much better educated scientists, who can maintain a hope of trying to catch up with the rest of the world. It is in this sense that he was the next Einstein.

We, of the Third World, must re-dedicate ourselves to carry on the mission of Salam, to return to our home countries and with a fresh commitment pursue the dream of development through the development of science. We, of Pakistan, have lagged far behind in our attempts. We did not give enough recognition to Salam – but worse, we let him down in his mission. Now we need to work all the harder to bring a more measurable success to his attempts for the betterment of his home country.

69.25 “Remaining Part of the World of Real Physics” by Dr. Igor Saavedra, Department of Physics, University of Chile.

As we all know, Professor Salam was certainly more than just a distinguished, Nobel-class physicist. He was also a passionate standard bearer of Third World science and scientists, ICTP being a paradigm of this. Personally, I feel much indebted and grateful to him. Without his unfailing support it would have been impossible to start and help developing a theoretical physics establishment of international status in Chile.

My professional relation with him extended for a number of years, having started when he was the external examiner for my Ph.D. thesis and, after the exam, he invited me to carry on my research work at his Theoretical Physics

Department, Imperial College, London, with a post-doctoral grant I had been awarded.

Later on, when my three-year grant was going to expire and I was completing five successive years in England (the first two as a student), I decided that I should return to Chile to start a research activity in theoretical physics in my country. Professor Salam reacted indignantly to this. In harsh words he told me that the proper way to be successful in that endeavor was exactly the opposite one, as he himself had previously done: to stay in the UK and get as high up as one could in the international physics establishment. Only then one would be able to effectively help young physics students in a developing country, as he was doing.

We sharply disagreed, as I thought that it was my moral duty to return to help young physicists-to-be become professional researchers in theoretical physics, because at that time (being Chilean) I was the only one who could do it.

I therefore went back to the truly "scientific wilderness" my country then was, and after less than two years I found myself (as a physicist) as a squashed lemon: I had nothing to teach concerning recent research results, I could only teach already-stale physics. I thought it was dishonest to carry on that way and that I should give up and return to Europe.

Then Professor Salam came to my rescue. He had succeeded in founding the ICTP and invited me to join him there. That was the beginning of my relationship with Trieste (and with Miramare later on) which was to last for many years, and my re-encounter with the stimulating air of the neighborhood of the frontiers of research. I started to return to ICTP every winter (the summer vacations for Chilean students) for three or four months each year, successively as a Visiting Scientist, an Associate and a Senior Associate of the Centre, all of them being schemes Professor Salam invented as years passed by to help people like me remain in the Third World and still be (or rather, feel) part of the world of real physics.

Today there are over one hundred active theoretical physicists in Chile and, as far as my own contribution to this effort is concerned, I can only say now, in spite of all our disagreements on questions of principle: Many thanks again, Professor Salam.

69.26 "Abdus Salam in Peru" by Dr. Victor Lattore, Multiciencias, Lima, Peru.

When I asked Abdus Salam what he had enjoyed most in Peru, he told me that it was the children in Pisaac (a small town in the Sacred Valley of the Incas, near Cusco), chanting *premio nobel, premio nobel* (Nobel Prize) after him. That meant that knowledge was likely to be appreciated anywhere in the world.

He had arrived in Lima in February 1980, fresh from Stockholm and having awakened the interest of the Peruvian military government, which had been

alerted by its diplomatic mission in Brazil. We, physicists in Lima, had been asked by our diplomats about his visit and his intentions. The military were actually on the way out, after eleven years in power. Elections had already been called, the same elections where Sendero Luminoso would make the ominous debut.

Abdus was always a practical man, so unexpected to the educated man who pictured a theoretical physicist as an absent-minded dreamer. On moving from the airport to the city he said to me: "Let us get together with a group of local active scientists and engineers, someplace quiet, and discuss one simple thing: what Peruvian physicists could best do to help raise the GNP of the country."

That same afternoon I took him to the house of don Mario Samame, our old revered Rector, who had already started to round up friends for our meeting. Our Foreign Office had continued to speculate on whether Salam would ask to see the President or not. Salam had already decided not to visit the President, but to informally call on the Foreign Minister, the only civilian in the cabinet. He was to slightly alter his decision in a way, as we will see shortly.

We started talking or rather listening to Salam, who loved loud and boisterous talking, but in time everyone contributed his ideas. Then all of a sudden I noticed he was gone and so I went to see what the matter was. The host, don Mario to us, did not speak English and I wondered what Abdus needed at the moment. I found them together in an empty room with the problem already solved. Don Mario had found a small carpet for Abdus to kneel on and say his prayers. The proper local time and the right direction to face had already been well determined.

We talked for two days with people coming and leaving all the time. Don Mario had been a presidential candidate in 1962 and had many friends. He was an authority on mining. The variety of Peruvian minerals is tremendous, but separation, identification and purification for proper pricing and exporting was hardly well done. Here was a field where physicists could help, using the spectroscopic tools of modern physics. I also learned then that the most scientific miners in the world were the Australians. They perforated rock with electron accelerators. The Europeans and the Americans of course had better science, but they did not have large mines to exploit like the Australians.

Abdus had seen the Foreign Minister and don Mario was now urging that we go to see the Mining Minister, an army general of course. A Centre for the Study of Minerals would allow the physicists to make their practical contribution.

Abdus had been to the offices of the Atomic Energy Commission and had discovered that the man in charge was also a general. He had been surprised to learn that a ten MW experimental reactor was under construction in Argentina for the Commission and had immediately asked the general what they wanted such a reactor for. It had the wrong energy: too high for conventional applications and too low for what "you have in mind".

So, Abdus was hesitant to see another general. But don Mario prevailed and we took him to the Mining Ministry. The Minister, forewarned of everything,

offered one hundred thousand dollars as the Government's initial contribution to the Centre. This released Abdus' full planning instincts. They lasted, I am sorry to say, for just a short time. That same year, a few months after Abdus' visit, the price of copper, Peru's biggest mineral export, fell in world markets to unthinkable depths. The Minister never got to release a cent for the proposed Centre.

Then came the visit to Cusco, the old Inca city near Machu Picchu, Peru's best known tourist attraction. "This is better than what my friends told me," said Abdus. Then, talking to the Cusco University Rector, he added: "The problem is that when I asked my friends about Cusco University, they said they didn't know there was a university in Cusco." Then and there a new summer school was planned, so learned Machu Picchu visitors could pay their visitors' fee by lecturing to Andean scholars. The school came to be called Multiciencias and is still in operation.

Celebrations after the founding of the school were too heavy and Abdus got ill and returned to Lima. He was, of course, in the best hotel in town. The hotel physician slapped Abdus' forehead on entering his room. The physician did not speak English, so Abdus asked me if he was supposed to slap the man back to conform to the rites of his religion. Not so! The physician was showing off the new fad in the profession. He had set a contact thermometer on Abdus.

He recovered quickly and was cheered up by two things arriving in his room. One was a collection of Peruvian fruit and another was a letter from a Peruvian physicist writing on a general relativity problem. He ate the fruit, but said that the problem was really outside his line. He would pass it to specialists in London.

In the airport, waiting for his plane, my wife noticed that Abdus' pants were held by a string, just like what Peruvian peasants use for the same purpose. She asked him whatever had happened to his belt. It had broken several weeks before and he had found no replacement of the proper size. Later I faced the same problem with the Peruvian alpaca sweaters that he loved so much. I could not find them big enough for him.

A year ago, alas, he had thinned much, but his spirit will never cease to grow among us, his colleagues and friends all over the developing world.

69.27 "Ideals and Realities: Working with Abdus Salam" by Dr. Sergio Mascarenhas, University of São Paulo, São Carlos, Brazil.

I first met Abdus Salam when by a stroke of fortune I shared an office with him in the Physics Department of Carnegie Tech in Pittsburgh in the ides of 1968. I was then a Guggenheim Fellow with the group of the late Roman Smoluchowski and he was there on a brief stay. We met again some years later in Stockholm for the creation of the International Science Foundation of which we were common proposers. I remember he and I were engaged (as usual) in a friendly dispute when Salam, who was sitting beside me, said he had no

influence on my proposal to model the International Science Foundation after the ICTP. Of course people laughed when I claimed not to be under the spell of Salam.

Little did I know that this man would change both my life and that of thousands of scientists from the Third World! And more, that his magic spell made of ideals and realities, dreams and incredible accomplishments, would bring a new vision of scientific and technological liberation to so many countries.

After Stockholm he invited me to Trieste as a member of a five-year planning committee of ICTP. For more than fifteen years I worked closely with him to organize several areas of applied interdisciplinary sciences like biophysics, medical physics and soil physics for which he gave full support and his enthusiastic collaboration. When I first proposed a series of colleges in these areas there was some criticism that they were out of the scope of ICTP, but he gave his firm approval, fully confident that interdisciplinarity and applied sciences are essential for the development of Third World nations. And he accepted to be the Honorary President of the Third World Association of Medical Physics (TWAMP), sponsored by ICTP. I had the great opportunity to discuss with him many aspects of the Third World Academy of Sciences (TWAS) and a possible platform for his candidacy to UNESCO. One of the dreams then was to have a UNESCO satellite beaming educational, cultural and scientific programs to the Third World in close connection with educational production centers located on different continents. The idea of a web to help jump the barriers of underdevelopment was very clear in his mind. The foundation of TWAS was a success, influencing and creating new leadership all over the world. Never before had the scientific community been so united about science and technology as the basis for progress and liberation from the chains of poverty and ignorance through self-reliance inspired by the creativity that often comes with science.

Salam was working all the time, writing, talking directly to world leaders, and most of all supporting young scientists who came from all over the globe to ask for orientation and help. Many came just to meet him personally, as if on a pilgrimage of the modern age inspired by love of knowledge and science. When he had more time in the beginning, I remember how we interviewed one by one all participants in the biophysics and medical physics colleges and how he listened to accounts of their difficulties at home, why they had chosen to come to biophysics or medical physics, demonstrating the tremendous personal dedication and authenticity of a man who was one of the greatest scientists of our century.

I always hoped that he would be nominated for the Nobel Prize for Peace but it seemed that fighting the war on poverty and underdevelopment was less important than being involved in real wars with guns and bombs. So this never happened, despite some timid proposals by some of us from the Third World.

Salam, as a tireless envoy for the cause of science and development, traveled all over the continents. I had the privilege of accompanying him to Mexico and China and saw the tremendous influence he exerted to help the foundation of

institutions and further their association with Trieste and among themselves in regional webs.

One aspect that I would like to stress in this memorial was his profound respect for culture, related not only to science but to art. When I mentioned to him that science should be important for the preservation of works of art from the Third World, one of our greatest treasures of creativity in China, India, Egypt, Mexico and many other countries, he gave his full support for the organization of a unique college on the theme, despite hard financial problems. This was held and was a success, paving the way for the creation of new methods for preservation, restoration and archaeometry. Not many would have had the vision and the sensibility to back these ideas.

My great joy was when he began to work in biophysics, proposing an audacious solution to the problem of chirality in biomolecules. As you may know, his proposal tried to bring his original contributions on elementary particles to molecular biophysics and the problems of the origin of life. This is still an open question, but we should not forget the dictum that "God speaks through the mouth of geniuses."

When I last saw him in Oxford he was very ill. Holding his trembling hands, I could still see in his eyes that incredible shining glitter that made his presence unforgettable to everyone who had the privilege to meet him personally and to be inspired by him.

Abdus Salam was the messenger of peace, the great scientist, the great statesman of science who called all Third World scientists to unite for the cause of freedom of knowledge and peaceful use of science as the only way to free mankind from the martyrdom of poverty and underdevelopment.

69.28 "Remembering Dr. Abdus Salam" by Dr. Fahim Hussain, Pakistan / ICTP, Trieste, Italy.

I have been privileged to know Professor Abdus Salam since 1963 when I joined the Imperial College, London as a graduate student in the Department of Theoretical Physics of which he was the head at that time. Also, I have been associated with the ICTP very nearly from its inception in 1963. I first came here as an affiliate in the summer of 1970 and then had many subsequent visits before I joined the ICTP as a staff scientist in the High Energy Group in 1990 with the special responsibility of running the High Energy Diploma program.

In this article I will not talk about Professor Salam and his achievements, which are well known but rather of the relation of the ICTP to Trieste and how Italy and Triestians view Salam and his achievements. In the early sixties, when Salam first proposed to the International Atomic Energy Agency the idea of setting up an international center for theoretical physics to help develop physics

in the developing countries, Triestian physicists, the Trieste authorities, and the Italian Government immediately took up this proposal and worked very rapidly and efficiently to set up the Centre in Trieste. At that time Trieste was going through a difficult period as it was in a remote corner of Italy and had lost its maritime importance as a port because its natural hinterland was in Yugoslavia. Also, Trieste was on the border with a communist country and thus on the borderline between the West and the East at the height of the Cold War. Thus the decision of the Italian Government was very wise in that it helped Trieste to develop as a science city and brought much-needed funds and publicity to the city. But more importantly, the site of the Centre at Trieste was also very symbolic as a bridge between the East and the West and the North and the South.

As everyone knows the ICTP soon developed a top class research institute and also a Centre, which aided the development of physics in the Third World. Apart from the Nobel Prize, Salam was showered with numerous prizes, both for his scientific work and for his immense role as an organizer. Unfortunately, Salam had to retire in 1994 due to his ill health. However, to those of us, foreigners and Italians, privileged to have worked with him, his ideas are still a guiding light in the running of the Centre. One of the senior scientific administrators recently told me how whenever some tricky question comes up he tries to think how Salam would have reacted! His is a continuing influence and his absence is very greatly felt. I used to think that only scientists from the developing countries had this great love and respect for him but I was surprised to find the same sentiments among the Italian scientists who were associated with him in the great adventure of setting up the Centre. All of them have been inspired by his ideal of service and continue to apply his ideas.

Recently, to honor him the ICTP library has recreated his office exactly as it was when he was here and have set up a beautiful display of all his degrees, honors and other mementa. One of the great aspects of Western societies and Italy in particular is how they honor not only their great politicians and military leaders but also their writers, poets, philosophers, scientists and thinkers in general. All over Italy you will find streets, parks, monuments, etc., named after Dante, Galileo, Michelangelo, Raffaello, Fermi, and others. What I find in Italy is the remarkable respect for intellectuals and the fact that common people know about their great artists, writers and scientists. They take pride in their achievements and children are taught about these people in school. In contrast, what do we have in Pakistan? We pride ourselves on being an Islamic country with a rich tradition which should in principle inherit all the best of the past, but apart from streets named after Iqbal, where are the streets and monuments named after Ibn Sina, Ibn Rushd, Jalal-ud-Din Rumi, Ghalib, Salam, Salimuzzaman Siddiqui, and others. We have streets and monuments only for local and foreign political leaders. Where is our respect and homage to our intellectual heroes? ■

70

Dr. Abdus Salam: An Epoch-Making Personality

Dr. Ghulam Murtaza

Abdus Salam Professor of Physics

Government College/GC University, Lahore

Anwar Dil: In the August 1997 issue of *The Ravi*, celebrating the 50th anniversary of Pakistan's independence, dedicated to "Nobel Laureate Dr. Abdus Salam, the great son of Government College, Lahore, and others whose creative efforts have made the college a bright tradition," I have read your beautiful Urdu article "Professor Abdus Salam 'ahd saaz shakhsyat aur 'azeem ustaad" that is an extension of your earlier Urdu article published in *The Nucleus* (Pakistan Atomic Energy Commission, Islamabad, 1996). Your first essay was a tribute to the great son of Pakistan on his seventieth birthday (January 29, 1996) who had become "a legend in his own lifetime" for his outstanding contributions to Physics that earned for him "a distinct place in the hall of fame, reserved for epoch-making luminaries." In your second essay written after his death later in the year on November 21, you call him "an epoch-making personality". It reminds me of C.P. Snow who in his chapter on Abdus Salam in his book *The Physicists that Changed the World* (1982) acknowledged him as "a leader in the theoretical developments in physics ... who ranks with the most eminent." Professor Freeman Dyson in his memorial article remembered him as "a great spirit of our time" who was "the voice of conscience speaking for the advancement of science among the poorer two-thirds of mankind" and that the international scientific institutions he created, and developed, notably ICTP and TWAS, are the lasting monuments to his vision of bringing the scientists and peoples of the world together in the service of socio-economic and cultural development of the human family. Professor Salam has also been called "modern day Einstein" for his work on the unification of forces and the Theory of Everything (TOE) that would have pleased Newton, Maxwell and Faraday.

Prof. Ghulam Murtaza: You knew him before I had the privilege of meeting him. I am glad you are doing a book on him. For me it is a matter of very, very great honor that I was his student and did my Ph.D. in Theoretical Physics under his guidance. In 1962, I had resigned from my lectureship in physics at the Punjab University, Lahore, and joined the Pakistan Atomic Energy Commission,

Transcript of some notes from a conversation with Professor Murtaza in his office in Government College, Lahore, December 5, 1997.

Islamabad. Soon after I was awarded a Colombo Plan scholarship for doctoral studies at Imperial College, London. I decided to study Theoretical Physics because I had heard of Professor Salam's great reputation in the field and also had attended his inspiring lecture chaired by the President of Pakistan in the Senate Hall of Punjab University in 1959. He was my hero and role model. I knew that he had gathered a distinguished group of theoretical physicists and the new Department under his chairmanship had come to be recognized as the best in the world.

I found Professor Salam's lectures fascinating in spite of the fact that very often I did not understand his high level discussion of the topics and had to work in the library for hours and also consult senior students and scholars especially Matthews, Kibble, Strathdee, and Lovelace. He usually brought a pile of books and journals with page-markers to cover a wide range of ideas in his lectures that were given at break-neck speed as if he was in a great hurry to reach somewhere. His blackboard was quite a sight with a variety of equations and symbols with arrows linking them here and there as if they were marching towards new frontiers of scientific exploration and unification of knowledge. Another unique factor that made his lectures so fascinating was the beauty of his language and a distinct literary flavor sparkling with his wit and subtle humor. I heard a number of his public lectures as well as his talks in highly specialized seminars and always marveled at the outreach of his brilliant mind.

Professor Salam had a very impressive upright personality with a certain sublime quality that made him a most effective and persuasive communicator. It greatly helped him win support for his initiatives in establishing and developing ICTP, TWAS and other international institutions. His eyes especially had a powerful shine in them that not only captivated you but also made it somehow difficult to say anything less than your very best in his presence. He had a way of understanding you as soon as you had started speaking on a problem and going straight to the heart of the matter started stretching your imagination in new, uncharted directions. Another personal quality that impressed me was that he was working all the time and loved every minute of it. It does not mean he did not enjoy himself or relax. His work was his enjoyment and relaxation. In fact, he used to laugh a great deal and more often than not it was a boisterous, infectious laughter. But even in such light-hearted moments he had a typical Salam flavor of elegance. He was a very generous man and is known to have helped a large number of students and deserving persons out of his personal savings. He never forgot his humble beginning and lived a very simple life in spite of the numerous awards and honors.

Professor Salam has done so much for his people and put Pakistan on the world map of Science. He deserves far, far more recognition and honor than we have given him.■

71

Dr. Abdus Salam Remembered

Dr. C.H. Llewellyn Smith
Director General,
European Organization for Nuclear Research, Geneva

When Abdus Salam died a year ago, the world lost a great scientist and citizen, and Pakistan lost a great son. The news of his death, on November 21, 1996, reached me when I was chairing the Research Board at CERN, the European Laboratory for Particle Physics situated near Geneva in Switzerland. This was highly appropriate because the Research Board was the body which in 1978, approved the modification of CERN's large proton accelerator to collide protons with their antiparticles (anti-protons). These collisions were sufficiently powerful to create the particles (called W and Z bosons) that transmit the so-called "weak force", which is essential in powering the sun. These particles were discovered at CERN in 1983 with the masses predicted by Salam, and independently by two Americans (Glashow and Weinberg) thereby confirming beyond a doubt their theoretical arguments, for which they had already been awarded the Nobel Prize in 1979, that the weak force and electromagnetism are different manifestations of a single "unified" force.

Latterly, Salam suffered from a crippling neurological disease, and he had effectively been lost to his friends and admirers for some years. Nevertheless, his death moved us greatly and focused our minds on how much we had lost; a wonderfully warm and sparkling human being, a scientist of profound originality, and a tireless servant of the developing world.

Salam's unified description of the weak and electromagnetic forces is intellectually as profound as the nineteenth century unification of electricity and magnetism which led to the development of radio and the other marvels of the electronic age. Indeed, in some ways it is more suprising since superficially the differences between the weak and electromagnetic forces are even greater than those between the first manifestations of electricity (sparks) and magnetism (attractions between certain stones). But Salam's list of scientific achievements contains others of almost equal importance as the experts will recognize (e.g., two-component neutrino theory; first grand-unified theory; invention of super space). His contributions were recognized by many honors. ...

In spite of some initial scepticism, ICTP was established near Trieste, Italy,

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in 1964. In its thirty-three years, it has hosted some sixty thousand visits, about half from developing countries, and the range of its activities has expanded from theoretical physics to computing, electronics, energy, environment, biotechnology and genetic engineering. For us in Europe, ICTP is a greatly appreciated center of excellence, but for the visitors from developing countries, it is a godsend.

Salam had no formal connection with CERN, although he was a frequent visitor, and from 1980 to 1986 a member of CERN's Scientific Policy Committee. However, his work inspired much experimental and theoretical work there including the discovery (in 1973) of so-called neutrino neutral currents which was the first evidence for his unified electro-weak theory. It was typical of his generosity that, on hearing that he had been awarded the Nobel Prize in 1979, he hurried to CERN to pay tribute to those who had made this discovery.

Salam appreciated the fact that, in experimental particle physics, CERN is playing the role that he envisaged for ICTP in theoretical physics. This has enabled scientists based in developing countries to participate in the exciting intellectual endeavor, and technological challenge, of exploring the fundamental structure of matter in large accelerator-driven experiments. Salam would have viewed the increasing collaboration between Pakistan and CERN with particular pride and satisfaction. Despite the demands of his own scientific work and duties as Director of ICTP, Salam was generous with his time both officially (he accepted some dozen assignments from the UN and from the government of Pakistan, including that of scientific advisor to the president). He was a tireless worker who was sustained by his deep religious faith.

To finish with Salam's own words: "The Holy Qur'an exhorts believers to study Nature, to reflect, and to make the best use of reason in their search for the ultimate. The quest of knowledge and science is obligatory to every Muslim from cradle to grave: Science is important because of the understanding it provides of the world around us, for the material benefits it can give us, and because of its universality. Science and technology are shared heritage of all mankind. East and West, South and North have all equally participated in their creation in the past as, we hope, they will do in the future, this joint endeavor becoming a unifying force among the diverse peoples of this globe."¹

72

Abdus Salam

Professor Freeman J. Dyson
Institute for Advanced Study,
Princeton



75. Freeman Dyson

Abdus Salam was one of the great spirits of our time, great as a scientist, greater as an organizer, greatest as the voice of conscience speaking for the advancement of science among the poorer two thirds of mankind.

I met him first in England when he was twenty-four, a student recently arrived from the turmoil of newly independent Pakistan. I was then supposed to be a leading expert on the theory of quantum electrodynamics. I quickly found out that Salam knew as much about that subject as I did. He asked me for a topic for his research. I gave him the topic of overlapping divergences, a highly technical problem that had defeated me for two years. He solved it in a few months.

I met him a year later in Zurich. He came with a completed paper, a pioneering piece of work on scalar electrodynamics. He asked me to introduce him to Wolfgang Pauli, at that time the leading European expert on quantum field theories. I told Pauli who he was, and Pauli agreed to see him.

After the formal introduction, Salam said: "Professor Pauli, could you please be so kind as to look at this paper and let me know what you think of it." Pauli said, "I have to be careful not to use my eyes too much. I will not read your paper." That was the end of the conversation.

Salam thanked Pauli and left the room, showing no trace of anger or disappointment. He knew his own worth. When I apologized for Pauli's rudeness, Salam said he was sorry for Pauli, not for himself. Pauli had missed the chance to learn something interesting.

When he visited Zurich, Salam was wrestling with the question, whether or not to return to Pakistan. His studies in England were almost finished. If he should decide to stay in England or America, a brilliant research career awaited him. He was at the height of his intellectual powers, an outstanding talent among the rising generation of physicists. But his conscience would not allow him to stay.

Excerpts from the article first published in *Proceedings of the American Philosophical Society*, 143, (1999).

He felt a compelling duty to go home and do whatever he could to help his people. Pakistan, in spite of its poverty, had paid the expenses for his living and studying in England. Now it was his turn to repay his debt to Pakistan. He discussed his dilemma with me. I advised him strongly to come to America, to plunge into research for five years first, and then help his people afterwards. He thanked me for my advice and told me he was going home. Physics could wait, but his people could not.

Salam returned to Lahore in 1951 and stayed for three years. Those were years of deep frustration. The academic hierarchy in Lahore had no wish to be helped by a 25-year-old genius. Salam had hoped to inspire the young people of Pakistan to learn science and modernize their society, to launch a wave of scientific progress.

All he could do was to teach mathematics and physics within the constraints of a rigid and antiquated curriculum. He felt himself growing rapidly out of touch with modern science and with the international community of scientists. After three years, he understood that he could help his country more from outside than from inside.

In 1954, he returned with a clear conscience to England and resumed his research career. In 1957, he accepted a chair at Imperial College, the position that he held for the rest of his life. As a London professor, he became chief scientific advisor to the President of Pakistan and wielded far greater influence on his native country than he could ever have achieved from Lahore. As his country's most distinguished citizen, he stood above academic hierarchies.

When I first met Salam in 1950 I recognized him as an intellectual equal, a young man who could solve mathematical puzzles as quickly as I could. Ten years later I could see that he had grown over my head. While I was still solving mathematical puzzles, he had come to grips with deep mysteries of physical reality. While I was exploring the details of old theories, he was creating new ones. For ten years he struggled, with many false starts leading into blind alleys, to create a unified theory of electromagnetic and weak interactions.

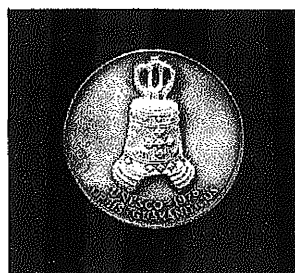
In 1967, he succeeded. At the same time as Steven Weinberg and Sheldon Glashow, working independently, he created the electroweak theory, the theory that was triumphantly vindicated by the experimental observation of weak neutral currents six years later. The electroweak theory set the pattern for all the ideas that were later incorporated in the standard model of particle physics. Salam and Weinberg and Glashow received well-earned Nobel Prizes in 1979 for this achievement. Salam quietly gave away a hundred percent of his prize to fund scholarships for poor students. He said that the Muslim faith by which he lived made it easy for him to be generous.

Meanwhile, Salam had founded the International Centre for Theoretical Physics in Trieste, the institution which fulfilled his dream of raising the level of fundamental science in poor countries. ... From the beginning, the Centre was not narrowly concentrated on particle physics. Meetings were organized and

visitors welcomed in many other areas of science, from plasma physics to environmental analysis and molecular biology. ... He maintained a serious interest in nuclear fission and nuclear fusion, both as sources of energy and as sources of challenging scientific problems. He believed that fundamental and applied science were equally essential to the vitality of developing countries. Visitors to the Centre worked mostly on fundamental science, but applied science was not despised. ... He bore much of the administrative load as Director of the Centre, besides providing the intellectual leadership. The Centre remains a monument to his energy, his vision, and his unselfish dedication to the task of bringing all peoples together in a common pursuit of science. ■



a. Marien Ngoubi University,
Brazaville, Congo, 1971



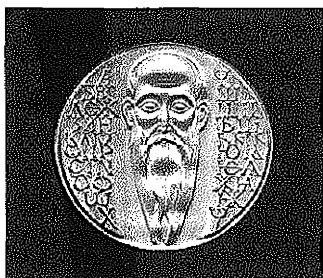
b. International Prize for Peace,
Unesco Centre, Florence, 1978



c. The University of Yaoundé,
Cameroon, 1981



d. Mu 'Tah University, Jordan 1981



e. University of Sofia, Bulgaria,
1986



f. The Edinburgh Medal, City of
Edinburgh, 1989

76. Some of Abdus Salam's Medals

73

A Great Synthesizer of the Century

Dr. Abdullah Sadiq
Vice-Chancellor,
Pakistan Institute of Engineering and Applied Sciences,
Islamabad

Europeans' sense of history is evident from all aspects of their living, their currency notes, their stamps, their monuments and the names of the streets and major structures in their towns. This sense of history seems particularly strong in Italy. Hence, it is quite understandable for Italians to honor their two illustrious countrymen, Galileo and Enrico Fermi. Galileo laid the foundations of the scientific method about four hundred years ago through his systematic experimental and theoretical studies. With the astronomical telescope that he himself had constructed he studied the heavens and reported the presence of mountains on the moon, the satellites of Jupiter, and the resolution of the Milky Way into numerous stars. His systematic studies of motion, especially motion under the influence of gravity, paved the way for Newton's law of motion and the universal law of gravitation. He was bold enough to defy the church authorities by openly advocating the Copernican system according to which the sun rather than the earth was at the center of the then known universe. For this he had to pay dearly and had to spend the rest of his life in isolation.

Enrico Fermi was a true intellectual heir of Galileo and one of the last of the renaissance scientists. He made equally fundamental contributions in both theoretical and experimental physics. Because of his basic work in quantum statistics his name is associated with several key concepts in this field. These include the Fermi-Dirac statistics, fermions and Fermi temperature. Through his theory of beta decay he postulated one of the four fundamental forces of nature, the weak nuclear force. His experimental work in artificial radioactivity and in nuclear chain reactions paved the way for the controlled as well as uncontrolled release of energy in nuclear fission. He was the leader of the team, which built the first nuclear reactor, which became critical in Chicago on December 2, 1942. Himself a Nobel Laureate he taught and groomed several future Nobel laureates such as Emilio Serge, Murray Gell-Mann, T.D. Lee and C.N. Yang. It is, therefore, not surprising that he is honored and respected not only in Italy, but also in his adopted land USA. P.A.M. Dirac, a teacher of Dr. Abdus Salam

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during his studies at Cambridge, was one of the greatest minds of this century. His unification of the special theory of relativity with quantum mechanics led to the prediction of anti-electron. The discovery of such particles, positrons, opened the possibility for the existence of a whole new class of matter, the anti-matter. The stairs going up into the Miramare Park were built and named after Dirac as a tribute to his revolutionary contributions to physics.

Salam was a great synthesizer of this century. He played a key role in the unification of two of the four fundamental forces of nature; the weak nuclear force postulated by Fermium and the electromagnetic force. The Salam-Weinberg model incorporating this unification forms the bedrock of the Standard Model of particle physics. In his quest to seek unity in the diversity of nature he was heir to the traditions of both Newton as well as Maxwell. ...

The honors showered on Professor Abdus Salam by Italians in general and by the people of Trieste in particular are well deserved. During my very first visit to Trieste some twenty-five years ago I became aware of the sense of respect of the common people towards him. His name was a household word in Trieste. On learning that I was from Pakistan, a person on the street would inevitably say, "Oh you are from the same country as Salam" and would become even more friendly toward me. It was not uncommon for prominent Italians, from the mayor of Trieste to the ministers in the regional and central government, to visit the Centre whenever an occasion demanded. This showed the degree of respect and esteem in which he was held. Salam was an ambassador par excellence for science in the developing world but more so for his country, Pakistan.

Now that he is no more with us, his name has been immortalized by re-naming the ICTP as the Abdus Salam ICTP. As one enters the Centre through its main lobby one sees his picture prominently displayed along with the souvenirs presented to him by his admirers from all around the world. His medals and certificates, including a replica of his Nobel Prize, are displayed in beautiful show cases in the new journals display section of the library right at its entrance.

His degrees, certificates and honorary degrees are gracefully displayed on the walls of a room leading to the rest of the library collection. All visiting scientists and scholars visit and pass through these areas. His office, the way he left it, with his books and wall hangings, has been recreated in a room just next to the new journal display section. A prominent painting of Professor Salam casts a welcome glance as one enters this room. A bookshelf next to his portrait displays the framed stamps with Professor Salam.

The international physics community and especially the Pakistani physicists, greatly value the graceful manner in which Professor Salam's memory has been preserved by the new management of ICTP. His outstanding contributions to physics and his tireless and fruitful efforts for the cause of science in the developing world will remain a source of inspiration and encouragement for future generations.■

74

Abdus Salam and Shaping the Destiny of Science and Technology in Developing Countries

Prof. M.S. Swaminathan

President, Pugwash Conferences on Science and World Affairs; Founding Member, TWAS; Chairman, M.S. Swaminathan Research Foundation, Chennai, India

I first met Dr. Abdus Salam in Cambridge in 1950. He was then doing his Ph.D. in Mathematics while I was doing the Ph.D. in Genetics. Even then Dr Salam became a legendary figure among scholars and scientists. Because of his intellectual brilliance he could complete his Ph.D. work within a year. Another record of his was the election to the Fellowship of the Royal Society at the age of 31 in recognition of his monumental work on the symmetries of particles, the most famous of which is "Omega-minus".

Later, I used to meet him at the International Centre for Theoretical Physics which he established at Trieste. He received the Nobel Prize in Physics in 1979 along with Dr Sheldon Glashow and Steven Weinberg. In 1980, Dr Salam visited New Delhi in connection with the felicitation functions organized by Scientific Academies in his honor. During this visit I had an opportunity to invite him to my house to discuss issues relating to science and technology in developing countries with particular reference to India and Pakistan. I was then the Chairman of the Science Advisory Committee to the Cabinet of India and also Member (Science) of the Planning Commission. He then mentioned to me his idea of starting a Third World Academy of Sciences (TWAS) with the initial membership covering Fellows of the Royal Society and the Fellows of the US National Academy of Sciences. I warmly welcomed the idea and accepted his invitation to become a Founding Fellow of TWAS.

TWAS over the years became a source of great inspiration and help to Third World scientists. Along with Prof Hassan, who is still serving TWAS in its new name "TWAS the Academy of Sciences for the Developing World". Dr Salam provided a new vision and impetus to the political leaders of the Third World. He was fond of quoting Jawaharlal Nehru, who once said "the future belongs to science and to those who make friends with science."

In 1990 when I was asked to chair the International Commission on Peace and Food, I requested Dr Salam to not only join as a Member of the Commission but also associate TWAS actively in its work. He graciously accepted this request

and hosted the first meeting of the Commission at Trieste. When we were meeting in Trieste, the Berlin Wall had been broken and Dr Salam felt that this was a good augury for diverting funds from weapons of destruction to development. Dr Salam was convinced, like the Roman Philosopher Seneca, that where hunger rules, peace cannot prevail.

I, along with Dr Salam, had the good fortune of presenting a report to the UN General Assembly in 1989 on the progress made in harnessing science and technology for the eradication of hunger and poverty in the Third World since the Vienna Conference on Science and Technology for Development held in 1979 at Vienna. I still recall the stirring call made by Dr. Salam to Third World leaders for fostering a climate for creative and innovative science which can address the problems of society.

Dr. Salam was an unparalleled leader of science for society. In this respect he resembled Albert Einstein, who once said, "Concern for man himself and his fate must always form the chief interest of all technical endeavors in order that the creation of our minds shall be a blessing and not a curse." Dr Salam's life and work will continue to inspire generations of young scientists not only in the developing world but all over the world.■



76. With M.S. Swaminathan, Food and Peace Conference, 1994

75

Abdus Salam – A Passionate Genius

Prof. Atta-ur-Rahman
Chairman, Higher Education Commission (HEC),
Islamabad

I first met Dr. Abdus Salam when he delivered a lecture in the Karachi University in 1964 when I was an M.Sc. student. He talked about his efforts to come up with a unified theory of matter. It was an exciting talk which even I as a chemist could understand. Later in 1969 when I was elected as a Fellow of King's College, Cambridge University and a report about me appeared in *The Times* newspaper in the UK, I received a letter of congratulations from Prof. Salam. We met on numerous occasions subsequently and became good friends, especially after I was elected as the Fellow of the Third World Academy of Sciences in July 1985.

I can say without hesitation that Prof. Abdus Salam has done more for the development of science in Third World countries than any other Nobel Laureate. His passion to help science develop in the Third World led to the establishment of the Third World Academy of Sciences which became a very dynamic organization that has been supporting the development of young scientists across the world. The International Centre for Theoretical Physics, now named after him, also developed under his guidance and has provided opportunities to thousands of bright young physicists to come and study in Trieste for various periods of time.

Prof. Salam wrote passionately on science in the developing world. I fully agree with his point of view that the future for the developing countries lies in giving the highest emphasis to education and particularly to science and technology. It is only through the establishment of world-class universities and Centres of Excellence in different fields that we can hope to progress in the knowledge-driven world. Unfortunately, in spite of extensive efforts by Prof. Abdus Salam, the Muslim countries paid little heed to his efforts and, with few exceptions, they continue to rely essentially on natural resources rather than human resources. As a result they together have a GDP which is less than half that of Japan!

Prof. Salam has left behind him a legacy of selfless dedication to science. The award of Fellowship by the Royal Society, London, and the Nobel Prize

were well deserved recognitions of his immense talents. It is now up to the leadership in the developing world to benefit from his various articles and to launch major programs aimed at unleashing the creative talent that lies in our young.

Prof. Salam visited my Chemistry Centre in Karachi on a couple of occasions and was deeply impressed that a world-class chemistry institute had been set up in Pakistan, where over one hundred students from advanced countries had come to study chemistry.

If Prof. Salam was alive today, he would have been very pleased to see the transformation that is happening in Pakistan in the field of higher education. A massive program to attract eminent Pakistani scientists, engineers and academics to return to Pakistan was initiated and about five hundred eminent persons who have lived most of their lives in the West, have already returned. About one thousand scholars are being sent abroad annually to universities in Germany, France, Sweden, Austria, Netherlands, UK, USA, Australia and New Zealand for M.S./Ph.D. level training. The largest Fulbright Scholarship Program in the world (US\$150 million) with funding from USAID and Higher Education Commission has been launched whereby six hundred and forty Pakistani students will be able to study for Master's and Ph.D. level training in ivy league universities in USA.

The salary structures of university teachers have been increased to several times those of Federal Ministers (upto US\$5,000 per month) under a new "Tenure Track System" which involves regular international assessment before grant of permanency. This is attracting the brightest young men and women to opt for careers in education and research as their first option.

The Pakistan Educational and Research Network, a fibre based intranet, is the platform of the Digital Library Programme of HEC which provides free online service to 23,000 international journals and 40,000 E-books from two hundred and twenty international publishers to universities and R&D organizations across the country. A well organized video-lecturing program of interactive lectures has been launched and daily lectures are being delivered from technologically advanced countries in real time to universities in Pakistan. Fifty linkages have been established between universities in Pakistan with British universities. Pakistan is setting up nine new engineering universities which in collaboration with Germany, France, Sweden, Italy, Austria, Japan, South Korea, China and some other countries, with degrees being awarded by foreign universities to students in Pakistan. An educational satellite placed in space (PAKSAT-1) in 2002 is being used for distance learning through four TV channels and cable TV. National Commissions on Biotechnology and Nanotechnology were established and large programs have been initiated in these fields.

These developments have been termed "a silent revolution" by the World Bank which recently carried out an in-depth analysis of the higher education sector in Pakistan. Pakistan is blessed with some 85 million persons (54% of its population) below the age of nineteen. This demographic advantage over many other nations must be taken both as a challenge and an opportunity so that Pakistan can transform from a largely agricultural-economy to a knowledge-economy.

However, we still have a long way to go before Pakistan can emerge as a country strong in any of the sciences. Sustained and enhanced efforts over the next 10-15 years can result in the production of many future Abdus Salams. However, we must create the necessary enabling environment so that our brightest scientists can serve in Pakistan and do not leave in frustration to 'greener pasture' in technologically advanced countries.■

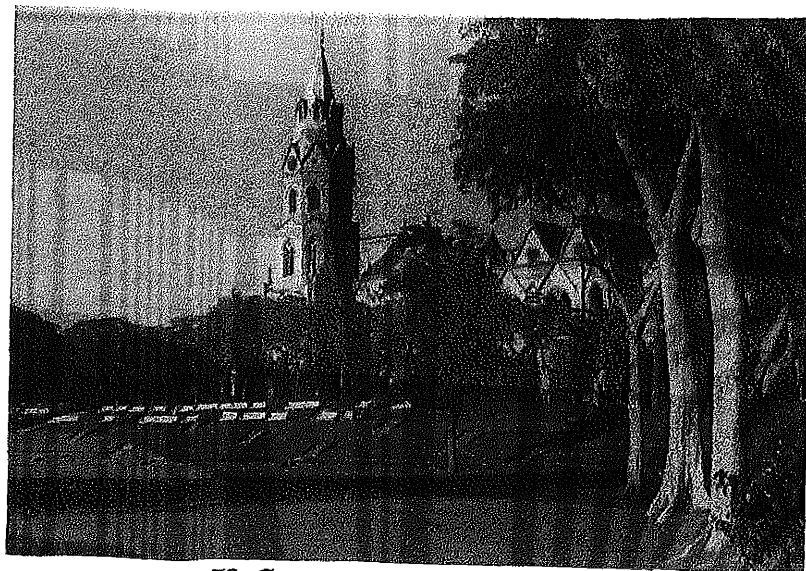
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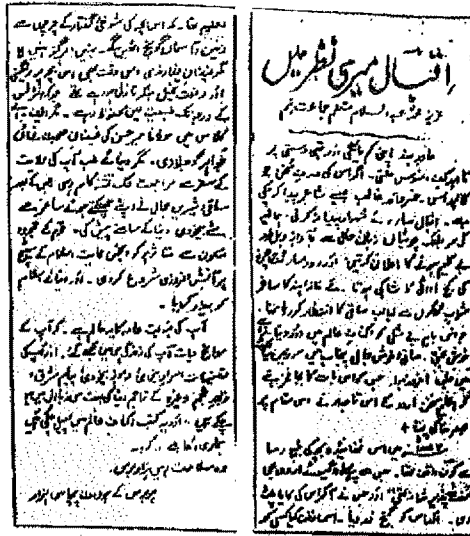
PART III.
ANNEXES



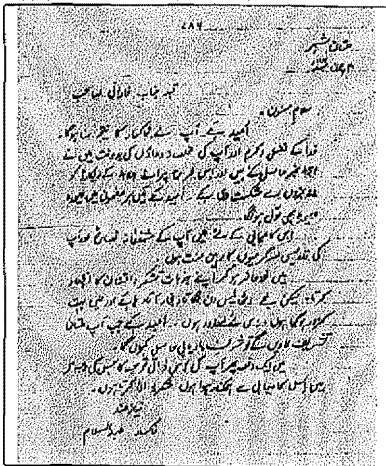
78. Abdus Salam, Student at Government College, Lahore, 1946



79. Government College, Lahore



80. 13-Year old Abdus Salam's Urdu essay on Muhammad Iqbal (1877-1938), written on the great poet-philosopher's first death anniversary on April 21, 1939. In the ornate style of classical Urdu writers, Salam wrote that if Iqbal, a poet of the caliber of Kalidas, Khusrow, and Ghalib, had not been born in India the majestic peaks of the Himalayas in their silence and the sublime water of the Ganges in its motion would have eternally complained to the Creator. Iqbal took world literature to new heights with his Urdu and Persian poetry, awakened the Muslim people with his clarion call, and shared his vision of a New World of human excellence. May he live for a thousand years and each year have fifty thousand days.



81. 14-year old Abdus Salam's Urdu letter to his teacher Mr. Farani thanking him for his challenging teaching, affectionate guidance, and prayers resulting in his creating a new record of highest marks in the matriculation examination of the Punjab University, 1940.

Annex I. "Hair and Hairdressers" by Abdus Salam. *The Ravi* (Magazine of the Government College, Lahore), Vol.XXXIX, No. 3, 1944, pp. 15-17.

Hair-dressing and shaving is one of the most atrocious ordeals that have yet been the gloomy lot of civilized humanity. I have always held that Rousseau's savage was noble – for the very plain and simple reason that he never handled a razor or scissors. Anthropological research may have failed to lift the veil that countless centuries have drawn across his immortal name – his, the pioneer of shaving and trimming – but the march of time has not abated the exuberance of those fervent excretions that all accompany tears, with every rake of the razor.

These superlatives may surprise some virgin chins. I may, therefore, adduce the account of Mark Twain's melancholy shave in Paris. From earliest infancy, he says, it had been his cherished ambition to be shaved some day in a palatial barber shop of Paris. "I wished to recline at full length in a cushioned invalid chair, with frescoed walls and gilded arches about me, and sumptuous furniture, with perfumes of Araby to intoxicate my senses, and the slumberous drone of distant noises to soothe me to sleep. At the end of an hour I would wake regretfully and find my face as smooth and as soft as an infant's. Departing, I would lift my hands above that barber's head and say, "Heaven bless you, my son!"

"I entered the shop; I said I wanted to be shaved, there on the spot. There was a wild consultation among the barbers, after which they took me into a mean little room, they got an ordinary sitting room chair and slopped me into it, with my coat on. My old, old dream of bliss vanished into thin air.

"I sat bolt upright, silent, sad, solemn. One of the villains lathered my face for ten terrible minutes and finished by plastering a mass of suds into my mouth. I expelled the nasty stuff with a strong English expletive and said "Foreigner, Beware!" Then this outlaw strapped his razor on his boot, hovered over me ominously for some fearful seconds and then swooped down upon me like the genius of destruction. The first rake of his razor loosened the very hide from my face and lifted me out of the chair. I stormed and raved, tears of exquisite agony coursed down my cheeks. Then the incipient assassin held a basin of water to my chin and slopped its contents over my face and into my bosom and down the back of my neck, with a mean pretence of washing away the soap and blood. He dried my features with a towel and was going to comb my hair; but I asked to be excused. I said with withering irony, that it was sufficient to be skinned – I declined to be scalped."

This is how this fraternity has made a conspiracy to victimize the human race. Worse still, barbers as a class have always been a proud people. In our

villages, where the fabric of a caste system is still intact, the barber represents the frontier between the upper and the lower strata of society. He is a surgeon, matchmaker and scandal-monger, all in one. For ages he has handled the knife of circumcision, with hereditary precision and skill. He must perforce be a high brow.

In fact his superciliousness may be traced, through the night of time, back to the glorious days of the great Caliph Haroun-ar-Rashid, the illustrious patron of this art. One night of all nights, so say the *Arabian Nights*, the excise sub-inspector hauled up a lusty roister, vociferous with drink and youth, and flushed with his late nocturnal revels. Waxing as black as Moses so quoth the reveller, "Defile me not, Heaven's anointed, with thy unsanctified hands. Knoweth thou not my illustrious parent – he who presides over multitudes, who outweeds the rebels, he to whom the whole world bows!"

They narrate that the dignitary stood aghast at the grim disclosure that beads of perspiration coursed down his brow, that he prostrated himself and apologized. Subsequent inquiries, however, revealed that the desperado was none else except the direct lineal descendant of a barber.

So it was stipulated that it is to a barber alone that the whole world inclines its head.

To one thing I can testify – that barbers do keep well abreast of the intellectual movement of the time. I can never forget the horrible yarns I heard some years back from the professional who exercised his shearing capabilities on the growth at my chin, blood curdling tales of murder, grim, gruesome, that would make my hair stand on end – and thus facilitate his work. Psychology in service of shaving!

What part have hair played in man's march to progress? Cleopatra's nose, they say, changed altogether whole chapters of Rome's history! Why not her raven black tresses? Pope has asserted in his *Rape of the Lock* that beauty draws us with a single hair. But this aspect of the question will lead us too far into aesthetics. Let it be merely stated that the growth of the virgin chin of their boy-beloved has had a mystic significance for our Eastern Sufi poets, proving for some the veritable road to Paradise.

Have hair anything to do with personal valor? Perhaps yes – for Shakespeare mentions the "beards of Hercules and Mars." The cases of Sampson and Shagpat may also be adduced.

Sampson on one occasion remarks:

"God, when He gave me strength, to show withal,
How slight the gift was, hung it in my hair."

No man could subdue him but his wife:

"Like a deceitful concubine, shore me,
Like a tame wether; no worthy match

But by the barber's razor best subdued."

When his hair grew again he recovers his strength and revenges himself on his enemies.

Similar was the case with Shagpat. According to Meredith, Shagpat wears his long hair, contrary to the custom of some countries, where all men shave their heads, with the exception of one tuft on the top of the head, by which tuft, after death, the true believer is to be lifted up by angels and carried to Paradise. Shagpat wears his long hair because in his head there has been planted one magical hair taken out of the head of a Djinn of Genie and this hair has the power of making all men worship the person on whose head it grows. From this it may appear it is not worthwhile to shave at all.

Apart from the diplomatic significance of long hair and beard in social circles, beard has a political significance as well. For myriads of historians the clean shave of Akbar heralded in a new era in Indian history. Recently, when King Farouq let a fine black beard to sprout on his comely face certain political observers forestalled the formation of a Pan-Arab Movement. Events have justified the significance they attached to what then appeared trifles.

But what has been the urge for me to write about beards and barbers.
Perhaps my own chin is itching and is almost overdue!
Who can say? ■

Annex II. "The White Arm" by Abdus Salam. *The Ravi* (Government College, Lahore), Vol. XXXIX, No. 7, 1945, pp. 8-10.

The temple looked a weird place in the gray streaks of fading dawn. Its turrets and spires stood out boldly like legend, heroes defying hordes of unknown foes. The bleak prospect of the surrounding stretch of land, its monotony unrelieved except by the distant curve of the riverbank that lended to its eerie atmosphere. The temple bells, after a protracted peal, had suddenly subsided. I called a halt to my men. The gray pile somehow seemed to draw on me. I said I would take my lieutenant and explore the place.

We crossed the threshold into a spacious courtyard – all deserted. To the right were steps which led into an inner apartment. The door was a massive one, heavily striped and studded over with brass nails. I rudely pushed it open and I entered – rather I did not enter. Like one rising from a torpor I grew conscious of the images displayed to my senses one by one, such was their bewildering multiplicity. The brain seemed to have lost its synthetic faculty. For a few seconds I could only smell – there was a gale of incense, voluptuous, excruciating in its sweetness. A few minutes later and I thought I had no sense of smell left. My nose seemed burned, whiffing like a bellows.

And then with a burst came music, low, plaintive, which trailed off into silence as suddenly as it had arisen. I felt I had risen from a dream – I could take in the whole panorama of light and shade; the idol was placed in a niche across the room in the center; I could not exactly discern its feature, limp in that mellow light; I think it was clay, plastered over with gold paper, all a blaze of finery. It was surrounded by black silk curtains; there was a shaded lamp of polished brass overhead. Beyond the curtains were galleries, passages, partially obscure, running into the back of the building; the typical mixture of gloom and light where any crime would be plausible. A priest stood in front of the idol chanting something in accents unknown. His tone was untrammelled, there was no undertones; as clear as a tuning bell. Three or four devotees were performing obeisance; one of them was sobbing. I could analyze every aspect of the senses. I knew the elements of that elaborate suggestion, that affect of shadows mingling with light, of that mellow atmosphere, of those mysterious chants not in unknown syllables, of that low sobbing. But still I could not combat the cumulative effect. My skepticism gave way. An incense of faith and devotion was stealing over my senses. I had read Rider Haggard's account of temples in African deserts, of the enormous power of suggestion and mystery, which the priests so well exploited. I had credited them as mere figments of fancy but now face to face with a heathen deity, I felt the very marrow of my bones will melt. I instinctively lowered my head in reverence and while in that act I saw what I had missed before. Through the curtains that surrounded the idol projected an arm, all-bare save for three glass bangles that clicked and danced, the arm of the lady of the lake. It was white, silver white, swinging a silver lamp, up and down with a graceful rhythm. The lamp surged up, lighted in a blaze of gold the finery of the idol. Its pale ringlet of smoke flickered for a second – up, down, down, up again, the idol twinkled, shimmered in its pale light.

Was that arm the secret of the charm – was she casting that spell? My feelings heightened; yes, I too felt a sob, struggling through the lump of lead in my throat. I felt I would stifle if I did not kiss that hand – I must hold it for a second, even if I pay with my life for it. I perfectly realized my act was sacrilegious, mad, but –

I surged forward, I caught the arm, while in its upward sweep, I lightly touched and kissed it, the curtains rustled and I saw her. It would be folly to call that seeing – I rather realized her – for the merest flicker of a second, I was vaguely conscious of a wild uproar, the silver lamp fell in a ringlet of smoke. I tripped over the idol and fell, a flash of lightening blinded me – and there was all dark. I lay unconscious at the feet of the idol.

The whole ilaqa [area] was in a wild uproar – I had sacrilegied the sacred precincts of faith, I had, with my touch, defiled the devi of the temple. I had been opportunely rescued from the fury of the priests by my men whose curiosity had superceded their obedience. My lieutenant a stolidier man than myself, had been moved, though not to such acts like myself. The commotion subsided but its

rumblings went on. Protests and representations were made at the Headquarters against my impetuosity.

But the white arm haunted me. Its three bangles clicked again and again in my ears. In sleep, in waking, I saw it wave to me, beckoning me onwards. I rushed to touch it with my lips – to clutch empty air, I saw the pale flicker of the silver lamp, I saw the fumes rising, chasing each other in leisurely curls. In complete nervous dilapidation I decided to resign my command.

It was a week after my adventure, I absolutely could not resist visiting the temple again – I must see the white arm; I carefully dressed myself as a native and went in perfect camouflage. I saw it again – yes there it was, perhaps rosier, with the same beautiful curve; its movements were distinctly less graceful, but still it held together, the atmosphere of the temple was the same. How I mastered my emotion I can never tell. Her arm was the symbol of that mysticism, the soul of all suggestion. The whole spell would crack and melt without it.

I returned to camp, with a silent resolve to get converted to the faith of the gods of the temple, to enter the temple as a priest to find her out, worship her all my life – my men startled me from a reverie. A corpse had been washed ashore that night – a woman's corpse. They wanted me to see it. An undefined and inexplicable dread clutched at my heart – could it be she. I had seen her arm that morning – her white arm but still my fears grew – till at last, when they uncovered her face for me I was absolutely prepared for it.

It was she – she whom I had seen so imperfectly that fateful night, she whom my heathen touch had defiled, she, who must have been the victim of the priests' wrath, she – the mistress of my dreams; but I had seen her arm that morning, could I be deceiving myself – my brain was in a whirl. I almost rudely shook off the sheet that covered her. What was that – was it true – was the corpse armless! Yes it was!

I came to the camp and tore off the resignation. I had a heavy score to reckon with the priests of the great temple.

**Annex III. "A Visit to Germany" by Abdus Salam. Written in 1948.
First published in *The Ravi* (Government College, Lahore), Vol. XLV,
No. 1, November 1951, pp. 13-17.**

I attended the 2nd International Youth Congress held at Munich from the 12th to the 20th of June 1948, as a Pakistan Delegate. The Congress was organized by Bayerischer Jugendring (Bavarian Youth Ring) – an unofficial youth organization and was sponsored by the American military authorities. About one thousand foreign and an equal number of German delegates attended the Congress. Besides the West European countries, almost all South American States, as well as India, Egypt, Syria and Pakistan were represented. No Russians were present – nor were there any Germans from the Russian Zone.

Four other delegates from Pakistan besides me were expected, but only one arrived. As a Delegation, we were thus at a great disadvantage as compared with bigger delegations, like the Indian – with about eighty members, or the Swiss and the French, with one hundred and fifty members each.

The Bavarian Youth Ring paid all our expenses from the time we entered the German border. Foreign guests, above thirty years of age, were accommodated in Munich town; some in hotels, and some others with private families. All others, under thirty, lived in tents, in Nymphenburg Park. The Tent-Town, as it was called, was divided into villages, each with its own *burgo-meister*. An equal number of German and foreign delegates lived in each tent. Each village flew the flags of the foreign nationalities living in it. In our village, we had Germans, Egyptians, Indians and Pakistanis. There were about two hundred girls in the camp – they had separate villages.

I traveled to Munich with the British Delegation. We went through Paris and at Karlsruhe – the border-town between France and Germany – we were met by the organizers of the Congress. And there we had the first taste of German hospitality. The trains were crowded – about as crowded as the trains in Pakistan, but the word “*ausländer*” (foreigner), always secured us a seat. It was as if the whole nation knew how to behave when people from foreign parts visited them. We traveled through some of the loveliest country in the Rhine valley – with neat little villages, the green countryside and distant mountains capped with snow. But for the crowded rags and the sad faces around us in the train, we might have forgotten that war had ever come to Germany. Occasionally we went through a crumbling town.

After about eight hours journeying in Germany we reached Munich. Buses were waiting for us and we were sent to our tent-villages for the night.

Next morning the Congress was officially declared open by the President of the Bavarian Youth Ring: “We have organized the Congress so that Germans could meet our foreign guests and they, in their turn, could know more of Germany. We must learn to fight the spirit of the weapons by the weapons of the spirit.”

He was followed by several other German speakers. Then the American Military Governor for Bavaria spoke. Addressing himself specifically to the Germans, he said: “Here is an opportunity for you to prove to the world that you want peace – to learn from others those lessons that were denied you during the years of Nazi regime.”

These speeches continued throughout the day, in fact throughout the week. But they were by no means the main theme of the Congress. The official program included visits to exhibitions, to operas and ballets and dramatic performances, and, most important of all, the “*Arbeitsgemeinschaft*” – the Discussion Groups. I can only briefly describe the official part of the program so far as I attended – for there were so many things going on at the same time that it was impossible to

attend them all. It was the camp-life, and the camp where in fact the real work of the Congress was done.

Munich has always been known for its immense variety of artistic performances. If the war has not affected one thing, it is this side of Munich life, and the organizers were generous enough to give us tickets for the various types of entertainment.

We were organized into different discussion-groups, each with a topical problem to tackle. I attended the discussion on "The Surplus of Women as a Social Problem". We were told that in Germany, in the marriageable age-group, there are 196 women to 100 men. I, together with some Egyptians who were also attending the same group, suggested the Islamic teaching about polygamy as the only solution. The discussion went on for three days. It was confessed by some Germans that polygamy was being secretly practiced in Germany; only they could not reconcile themselves to it on sentimental grounds. I gave them the figures for Pakistan and pointed out that we had just the reverse problem, with 85 women to 100 men in our country. This occasioned a humorous suggestion in a local paper which, under the caption "Splitter" said: "No women surplus in Pakistan. Where is the bus to be got? I could just as well take a full one home with me."

Our food in the camp was adequate but uninteresting. We started the day with breakfast, consisting of black bread, jam and coffee (the German variety); the mid-day meal consisted of soup and potatoes with a flavoring of meat. At eight in the evening we got a piece of cheese and bread. We were told that our daily ration of cheese was the same as a German's weekly ration.

Throughout the day we met lots of eager listeners, eager to learn about us, about Pakistan and its problems. The foreigners were for them a mystery, they never had seen so many from so many different parts of the world. They were eager to take us to town, to show us around, to make us feel comfortable, to serve us. It almost appeared as if they acted under instructions. At night they came to our tents, girls and boys, and they sang and danced for us, till late into the night, making us sing and dance too. It was a strange life, of a whirlwind of contacts, of a thousand friendships, of loving informality.

But outside the camp, life had sterner realities. Germany was never so low at any other period in its long history. The German problems were the most elementary; food, clothing, and housing. I shall briefly describe what I could see around me. It may be remembered, however, that Bavaria had no big industry, and that it suffered far less devastation than some other parts of Germany.

The German food position is truly desperate. The monthly ration of meat is four ounces. There is even less cheese, fat or sugar. They get fifty pounds of bread per month, and only this dark, dry bread keeps them alive, it appears. There

is no milk, no tea, and no coffee – they have found a substitute for coffee – a horrible bitter type of herb. One cup of this coffee is sold for half a mark – while a cup of real coffee may be obtained on the black market for twenty-five marks.

Then again there is the problem of currency. While I was there, the new currency had not yet been introduced. So all my observations refer to the old Reich Mark. There was inflation in Germany; there was absolutely nothing to sell in the shops. There were two classes in Germany; those who had millions of marks earned probably on the black market, and the others who literally had nothing. We carried out a survey of social conditions among Munich working classes. Of those we interviewed there were two manual workers who were shop assistants during and before the War; bombed out; now employed in removing brickwork for new foundations; working forty-eight hours a week, they both lived in one room which cost them fifty marks each. Each earned one hundred and fifty marks per month. Each paid insurance, about ten marks. Their official ration cost them about thirty-five marks each. This left them with fifty-five marks – with which either to supplement their rations on the black market, or to buy cigarettes – at five marks each – or to go in for an article of clothing.

We interviewed another family of six – they were refugees from Silesia now a part of Poland. They were living in a wooden hut, erected in one of the open spaces cleared by bombing. The hut was sunny and clean, but it was a miracle how six people squeezed themselves in it. They complained of the insects that pestered them night and day in their wooden habitation; complained, when questioned of the corruption of officials distributing food, of lack of sympathy among Bavarians, and of refugees from other parts of Germany. They would very much like to go back if they could, but they saw no prospect of it ever being possible. For people like them even these worthless marks were grimly vital.

There was a strange reluctance among the Germans to talk of the war. There was very little consciousness among them of any war guilt. It was the Nazi Party that did it; they were not responsible. Regarding Hitler, I was repeatedly told that he had hypnotized the nation. There could be no resistance against him for in his armies fought their brothers, sons, husbands. They were silent, cheerless, patient. They did not grumble. They had not yet recovered from the daze of their defeat. Almost everyone I met had lost some relation in the War. If they were bitter, they did not show it. They wanted to forget it. And they wanted to forget not only the War they had come out of, but also the coming War, even now being fought on the German soil.

On the way to Munich I was talking to a German engineer. I asked him what he thought might be the future of Germany in this struggle between the East and the West. With a set face he said: "Half of Germany will fight the other half. We shall have to give soldiers to both camps." And then, pensively, he added: "I have four children: two boys and two girls. They boys will become soldiers and die. The girls will end – God knows where?"

There were surprisingly few outward signs of occupation; in Munich at any rate. I seldom, if ever, came upon any American soldiers – the police in towns was almost entirely German. The only visible signs of occupation were the very large elements of German population speaking English, with the Yankee accent. And the notices at railway stations, with “Entrance for Americans” as distinct from the “Entrance for Civilians”.

The Germans tried to make us believe that they did not think of the occupation at all. But what they really felt did come out sometimes. I was speaking to a girl from Hamburg. She was describing the systematic bombing of her town; when they had finished with one quarter, she said, they would start the next day exactly at the place where they had left off the day before. I asked her if there was any pretence of bombing military objectives. “Good Heavens, no!” – she said, and then screamed out: “And that is why we hate them!” Immediately after she corrected herself – “why we hated them!” But she had let the cat out of the bag.

And then the Germans sang. That was the most amazing thing about them. They could sing anywhere at any time – while bathing, eating, drinking, on the trains, on the pavements. One would start a song and fifty others would join in. They sang of the sun and the stars and of their loves, and thus they worked themselves into a mood of collective mysticism, quite peculiar to their race. We in the East too are sentimental, we too are mystics. But our mysticism is individual.

On the last night before the camp broke up we had what they called “a camp fire”. A fire was built up in the center and speeches were made addressing the “Fire”. The note of high seriousness was almost alarming. They gradually worked themselves into a mood when anyone could have swayed them for good or for evil. A young girl near me was weeping copiously. It was her turn to go next and speak. There is a very real danger that the Germans may again play into the hands of an adventurer.

But I must end on a note of admiration. The very fact that the Germans, of all people, should be holding such youth rallies, testifies to the life of the nation, to the vision of, at least, some individuals among them. The way those German boys and girls treated us was a marvel in itself. If the Congress succeeded in nothing else, it at least gained for Germany as many people who would wish it well. When, on the 20th, we left Munich, our hearts were heavy. We felt we were leaving very dear friends behind. ■

Annex IV. "Homage to Chaudhri Muhammad Zafrulla Khan"
by Abdus Salam. *National Perspectives*, Vol. 12, No. 2, 1986.

Chaudhri Muhammad Zafrulla Khan was one of the greatest human beings I have had the privilege and good fortune of knowing in my life.

I first saw Chaudhri Zafrulla Khan Sahib in December 1933 at an annual gathering. I was then nearly eight years old. I can still see him in my mind's eye – a very handsome figure with a most impressive bearing. I believe the first occasion when he knew of me was when my father wrote to him in 1940 seeking his advice about my future career. He wrote in reply that he would pray for me and he offered three pieces of advice. First, that I should look after my health; health was the basis of all achievement. Second, in respect of studies, he advised that whatever lectures in the classroom were due for tomorrow, I should prepare for them the day before. And whatever I learned today, I should revise the same day so that it became forever part of me. Third, I should broaden my mind; in particular, whenever I got the opportunity to make an educational journey – or even a journey for pleasure – I should take it, for journeying to new places was conducive to a broadening of one's range of interests.

My first personal contact with Chaudhri Sahib was in October 1946, when I sailed to the UK to join Cambridge University for studies. Our boat – the P. & O. Franconia – docked at Liverpool. It was a cold and misty morning. Chaudhri Sahib had come to the dockside to meet his nephew who was also traveling on the Franconia. Chaudhri Sahib was at that time Judge at the Supreme Court of India. When we got down from the boat, our heavy cases – my mathematics and physics books which I had packed in them – were lying around in the customs shed. There were few porters due to post-war conditions. Chaudhri Zafrulla Khan said to me, "Take hold of the case from one side and I will take it from another and we shall carry it to the waiting boat train." This was an amazing reception for a humble student, who had never before encountered such gracious unself-consciousness on the part of a personage so highly placed.

We traveled together to London. During the journey he kept pointing out the beauties of the English countryside, of which he was inordinately fond. The weather was very cold. Seeing me shiver, he kindly gave me one of his (enormously heavy) winter coats. This, in spite of forty years of use, still survives in the family.

I met him again in 1951 when he was the Foreign Minister of Pakistan and came to the Princeton Institute for Advanced Study where I was a Fellow. I spent two days in his company. He was then attending the General Assembly of the United Nations. With him I had the privilege of visiting some of the beautiful historical places on the East Coast of the United States. Fresh from his

memorable duels at the United Nations forum, fought with the highest ranking and keenly brilliant adversaries, on behalf of the Palestinian Arabs, Libya, Algeria, Morocco and for Kashmir, my chief recollection of him is of one who would not suffer fools gladly.

But I really got to know him after 1973 when he came to live at the London Mosque after his retirement from the Presidentship of the International Court of Justice. He was gracious enough to accept to come to my house at Campion Road, nearby, for Sunday breakfast. He spent all his time working on his translation of the Holy Book or Books of the Hadith and the like, starting regularly at 9 a.m. every day, including Sundays, and could not be interrupted.

These breakfasts were memorable occasions when sometimes we would go over the public episodes in his life which are so beautifully described in his books, particularly in his last memoir, *Servant of God*. But this does not convey the lively details, which he would narrate to us. For example, he tells the story on pages 67-69 of his encounter with Mr. Churchill, but he omits the earlier parts of this story when Mr. Churchill was cross-examined by Sardar Boota Singh of the Indian Party and the hilarity of that examination. Even so, I shall quote here the story as he himself tells it to convey some of the wonderful flavor of his narration:

The public sittings of the Joint Committee commenced in the spring of 1933. A large variety of witnesses, Indian and British, representing a diversity of interests and views was examined by the Committee. Participation in the proceedings of the Committee proved a very instructive experience. The most outstanding witness who appeared before the Committee was Mr. (later Sir) Winston Churchill. His examination extended over four days. He was firmly opposed to the proposals contained in the White Paper. He condemned them lock, stock and barrel. He looked upon them as a betrayal of its trust by Britain. The barrage of questions directed at him failed to move him a single inch from his stand. His eyes twinkled, he wore a smile, he waved his cigar, he was all courtesy and urbanity, but he was utterly unyielding. His questioner could win nothing from him. He held his own against all comers.

Having watched the drama for a whole day, the Punjab Muslim Delegate felt that it would serve no useful purpose to cross-examine so formidable an adversary as Mr. Churchill. On the morning of the second day the Secretary of State accosted him before the meeting was called to order and enquired: "Do you intend to put any questions to Mr. Churchill?"

"No Sir. I consider it would be a profitless exercise."

"Well, he is our cleverest debater in the House, and it is no use trying to catch him out on his previous speeches in which he supported Dominion Status for India. You have seen how he gets out of them. Yes, Dominion Status, but status is one thing and function is quite another. India already has

Dominion Status. It sent a delegation to the Paris Peace Conference, it is a signatory of the Treaty of Versailles, it is a member of the League of Nations. That is status. But it is not yet ready to function as a Dominion! He thinks India is still what it was when he was serving as a subaltern at Bangalore!"

The Muslim delegate thought it over. His turn came an hour before the close of the afternoon sitting of the Committee. His attitude was deferential, his tone respectful, bordering almost on the apologetic, with a slight touch of deference. Mr. Churchill was cautious, but made a reluctant concession here, a grudging admission there, hedged round with ifs and buts and provideds. When he perceived that he was letting himself be persuaded to yield his ground, he began to evade the question put to him, so that it had to be reframed with great care. On one occasion he slipped out of answering the question in one direction, and when the question was carefully rephrased he slipped out in another direction. The questioner's tone became even more bland, almost humble: "Mr. Churchill I beg to be forgiven. I am under a disadvantage. English is not my mother tongue. I have twice failed to make my meaning clear. Will you permit me to try once more?" The response was gracious: "Please, please." The question was put a third time in a shape that did not admit of evasion. Thereafter both the examiner and the witness became more alert. The Committee adjourned. The examination was resumed next morning and continued for another hour. When the questioner concluded with an expression of thanks to the eminent witness, the witness went on record with: "My Lord Chairman, may I be permitted to say that I have not noticed that Mr. Zafrulla Khan suffers any disadvantage from lack of knowledge of the English language."

When at the end of the fourth day his examination was completed, the cheers of the Committee had the quality of an ovation. (Mr. Churchill) rose from his seat, came over to his Muslim interrogator, shook him by the hand and growled: "You have given me the two most difficult hours before the Committee." The questioner acknowledged the growl as if it were an accolade and a token of friendship and so it proved. In subsequent meetings the great Prime Minister would every time present him with a volume of his letters or speeches, and the inscriptions beginning with: "Inscribed for Zafrulla Khan, W.S. Churchill" went on mounting the scale: "To Zafrulla Khan, from W.S. Churchill; "To my friend Zafrulla, from W.S. Churchill"; "To Zafrulla from his friend W.S. Churchill." Magnanimity was not the least among the many great qualities of the great Prime Minister.



82. Zafarullah Khan

The amazing thing was that Chaudhri Sahib's memory was faultless, not only about persons, but also about dates and even times of day, for matters which had occurred fifty or sixty years earlier. I also recall with great fondness the narration of his United Nations fights with Big Powers for independence of Libya, Morocco, Tunisia and Algeria (described on pages 179-182 of *Servant of God*); likewise, the heart-warming story of his pilgrimage to Makkah, where he was King Faisal's personal guest, narrated on pages 279-286. In the recounting of all these incidents in his life, what came across strongly was the greatness of his spirit, his intense love – bordering on

near-adoration – for the Holy Prophet of Islam, and his own complete reliance on Allah and His Divine Will. Also manifest was his love of Persian poetry, of Hafiz and particularly of the mystical verse of Rumi in his *Diwan-e Shams Tabriz* which he could recite without effort from memory.

Regarding his love for the Holy Prophet, let me tell a story. Chaudhri Zafarulla Khan was taken ill with a back-ache and was confined to bed in a hospital in Wandsworth. I visited him in hospital. I took to him *Shamail Tirmizi*, written by Imam Tirmizi, which describes the Holy Prophet's daily life, his looks, what he wore, his daily preoccupations, his family and public life. I said I hoped that sometime in the future, if Allah decrees, I would translate this book into English. I left it with him and went away to Trieste.

I came back a couple of months later and went to see him at his residence. He presented me with a copy of a translation of Tirmizi into English, already completed and printed, with a gracious dedication to me. I was astonished at the speed with which he had worked. I mildly protested: "I had wished to translate this book myself for my *ghufrān* (salvation)." He said: "You may not have found time in the immediate future. So I thought while I was confined in the hospital, this would be the most rewarding use of my time."

My last travel with him was when he was invited in 1980 to the inaugural meeting of the Academy of the Kingdom of Morocco, by its Permanent Secretary, the late Dr. Ahmed Taibi Benhima, who knew him from the United Nations days. Chaudhri Sahib was then eighty-seven years old – an erect figure, commanding, yet benign. I can vividly recall him sitting next to His Majesty King Hassan at the banquet and at the subsequent function, receiving the King's

personal affectionate homage. I saw the same veneration for him in the streets of Fez from students, soldiers – everyone who heard of his name – for what he had done for Morocco's independence.

I have earlier said that he was generous – almost to a fault – to those in need. The story may not be well-known, but after retirement, he dedicated all his life's savings to charitable purposes. A large part was spent in rebuilding the living quarters and offices for the Imam next to the London Mosque, as well as towards building the Hall (he did not want any mark, commemorating his generosity, on the building). The rest – of the order of half a million dollars – he dedicated to setting up a charitable Foundation – the Southfields Trust – to help the needy, and for educational purposes.

One Sunday when he honored us with coming for breakfast, my brother protested to him on generally neglecting his own personal needs. Chaudhri Sahib said he had asked his yearly pension (of around \$32,000 a year) to be deposited straight into the bank account of the Foundation he had created. He did not keep any part of his pension for himself. But he had an agreement with the Trust that it would pay him seven pounds a week for life's necessities and once a year the Trust would permit him an economy fare to Pakistan to attend the annual gathering in December. He then added, "I know, through Allah's grace, I am a good advocate, but one judicial case I always lose. That is, whenever I plead to myself for myself."

He had such love for Islam, and such a *ghairat* (devotion) for his faith, that one could not come away from his company without being fired with his spirit. It is well-known that he spent the last years of his life occupied with his translation of the Holy Qur'an and the introduction to it, his magnificent biography of the Holy Prophet (Muhammad, Seal of the Prophets), published by Routledge & Kegan Paul Ltd. of London, with translations of works of Hadith, as well as several works on Islam, creating single-handedly a veritable one-man Library of Islam in the English language. He said he had left the International Court of Justice, where he could have continued for another term of office, to serve Allah. As he says himself, "Gradually, over the years, the consciousness of God as an experienced reality, rather than as merely believed phenomenon, was strengthened."

His love for his long-departed mother and the lessons he had learned from her were often repeated for us. In his book, on page 297, he quotes her as saying, "It is no virtue to be kind to someone we like; virtue is to be kind to those we do not like"; and then, "A friendship is for ever, else it is no friendship at all." A mark of this, and a real privilege, was to be included in his prayers at *Tahajjad* every morning when he said he prayed for three hundred persons, naming each one individually. His own oft-repeated saying used to be: "Call to mind when your Lord declared: If you will employ My bounties beneficently, I will surely

multiply them unto you; but, if you misuse or neglect them, My punishment is severe indeed." (*Al-Qur'an*, 14:8)

I cannot do better to close this note, than by quoting from the last words of his last book *Servant of God*, where he speaks about himself.

His career as a public servant came to an end with the expiry of his second term on the International Court of Justice. He was called to the Bar at the age of twenty-one years, practiced as a lawyer for twenty-one years, held executive office in India and Pakistan for fourteen years, was a Judge, national and international, for twenty-one years, and a diplomat for three years. He has worn many hats, but the one he now wears is the most honorific of all, and brings him the greatest satisfaction. He is now wholly the servant of God, for which honor and all praise is due to God. His one care and concern is that his Gracious Master may be pleased with him, and may continue to afford him, for such time as He may, of His grace and mercy, grant him here, opportunities of serving Him and His creatures, and bestow upon him the strength and ability to perform that service in a manner acceptable to Him. Of his own he has nothing to devote to His service; life, faculties, capacities, means, relations, friends are all His gifts. He supplicates for wisdom and strength to employ all his gifts in His service, to the winning of His pleasure, to the true service of his fellow beings. For himself he only seeks fulfillment in his Gracious Maker, Creator and Master. He hopes for His mercy, His forgiveness, His forbearance. May He continue to cover up all his numberless faults, defaults, shortcomings, vices, sins, disobediences and transgressions under the mantle of His mercy, and safeguard him against humiliation here and hereafter. May He wash him clean of all impurities so that death, when He is pleased to send it, may prove to be a gentle transition from illusion to reality, from faith to fulfillment and utter submission. Amen. All praise belongs to Allah.

Annex V. "Poor as a Nation" by Abdus Salam. Transcript of a talk to Pakistani students, 1987. First published in *The Ravi* (Government College, Lahore), Pakistan's Golden Jubilee Issue, 1997, pp. 4-11.

I was admitted to Jhang College, Pakistan, in 1938 at the tender age of twelve. I spent four years there. In those days it was an intermediate college, grades nine, ten, first year and second year classes were taught there. The majority of students in the college were Hindu. It was my good fortune that I had some of the exceptionally learned and most affectionate teachers assigned to me. Shaikh Ijaz Ahmad was my English teacher, Soofi Zia-ul-Haq was my Arabic teacher, Khawaja Miraj-ud Din taught Persian language, while mathematics and science subjects were taught by Hindu as well as Sikh teachers. Science and mathematics in those days were considered to be the domain of Hindu and Sikh students. Lala Badri Nath and Lala Ram Lal taught mathematics with great proficiency, while Lala Hans Raj taught physics, and chemistry was taught by Lala Naubat Rai.

The foundation of my academic career was laid in this college. I believe that I owe all of my later accomplishments to this institution and to its hard-working

teachers. I firmly believe that a teacher's affection and his proper attention can make or break a student. To give an example, in my first year of college I got into the habit of using some English words which I liked very much. I started to use these phrases in my daily conversation without proper context. My respected teacher, Shaikh Ijaz Ahmad, forbade me to use such difficult words but the advice fell on deaf ears. When the semester ended, my English teacher penalized me by deducting five points for every difficult or improper word I had used. The outcome of my English exam was quite obvious. My teacher did not consider it sufficient and decided to bring my paper to the classrooms, to announce in the entire school how I had used improper English words in my examination. At the time I did not appreciate the treatment meted out to me by my teacher but now I think back and feel that it was the proper medicine administered to me. The net result of this shock therapy was that I stopped using difficult words altogether.

The education I received was due, in large part, to my teachers, but it was above all to my illustrious father's benign attention and his fervent prayers for me. In those days matriculation exam was more like a wrestling match in the province of Punjab. Wrestlers from various schools would show their prowess through this exam, especially students from Hindu Sanatan Dharam and Arya schools were considered to be formidable wrestlers. I vividly recall the day matriculation exam results were out. I was sitting in my father's Jhang courthouse office. The exam results were published in newspapers from Lahore and on that day the newspaper arrived around lunch time at Jhang railway station. My father had instructed one of his subordinates to bring the newspaper to him right away, and in no time telegraphic messages of congratulations started pouring in from Lahore. As I mentioned, matriculation exam results were sort of a national event in those days. I remember returning home around 2 p.m. in the afternoon on my bicycle from Maghiana to Jhang city. I had to pass through the District Police Gate of Jhang city to reach my home in Buland Darwaza. I distinctly recall that those merchants, who normally would have closed their shops due to afternoon heat, were standing outside their shops to pay homage to me. Their respect for me, and their patronage of education, has left an indelible impression on my mind.

From Jhang I went to Government College, Lahore and then to Cambridge, England. In Cambridge I experienced and learned a variety of new methods of study from English students. In Cambridge, students sit in their classrooms in such a respectful manner, as Muslims sit in a mosque for prayers. Before the lecturer's arrival there is pin-drop silence. During the lecture you could see that students used ball-point pens with four types of ink and rulers to draw straight lines. Students' note-pads were written in such a professional manner as if written by a calligrapher. My classmates had come to Cambridge straight from schools. They were younger than me in age but their self-reliance and high resolve was of such a degree that it took me two years to achieve the same

standard. My class-mates had studied in such schools where teachers prepared their pupils for advanced education and reminded them that they were sons of a great nation in which was born a man like Sir Isaac Newton. The teachers drilled in the children's minds that they had inherited the deep knowledge of science and mathematics and they too could become Newtons.

In Cambridge, the method of discipline was completely new and surprising for me. You could sit for the B.A. exam only once. If heaven forbid you failed once, then you could not sit for this exam again. The discipline in student hostels required every student to be back in his residence by 10 p.m., if you came back before midnight the fine imposed was one penny, but if a student returned after midnight, the penalty was gating for a period of seven days. If it happened three times during the academic year, a student was expelled from the university. Every student was treated like an adult, he was accountable for all his deeds. A student did not engage in useless discussion as punishments were equally exemplary which some students accepted with fortitude.

A Cambridge student was expected to do some work with his hands as well. I remember my first day at St. John's College in London, England. When I arrived there, my forty kilogram luggage bag was brought from the railway station by a taxi driver. On arrival at the college I asked a porter for help. He pointed towards a wheel-barrow and told me to help myself. These incidents I am narrating here not for the sake of pastime, but the subject at hand is education, whereby these anecdotes become part of getting a point across.

You must ponder over the fact that there is a vital link between our economic downfall and education. Misleading and rather inappropriate education is in fact a national crisis right now. I believe that our nation is passing through a grave crisis for which the reason is that a proper educational system has not been developed.

The primary purpose of an educational system, in my view, is to develop a person's character. A character that is developed during school years seldom changes for the rest of a person's life. Here, however, I am not going to dwell on personal character. My reference is towards national aspects of our educational system. God Almighty has, at last, endowed us with freedom after two hundred years of slavery. This momentous event took place some forty years ago but up to now we have not cultivated any feeling of belonging, brotherhood, oneness, and of being a unique nation.

The fact of the matter is that once we had achieved freedom, it should have been the primary objective of our educational system to strengthen our sense of belonging and nationality. The idea of nationality has been gradually changing in various regions of the earth but in today's world many countries can be cited whose consolidation as a nation solely depended on the type of educational system they developed for themselves. Take for instance the United States of America where Germans, English, Italians, Swedish and French people are living as one great nation. The reason I mentioned America here is that people from

these European countries gave their lives during the last world war for the sake of a separate identity. These people in the United States spoke various languages before they arrived in America. In schools the American children are familiarized with the American constitution, American folk heroes are always at the tip of their tongues, day and night these kids listen to the American national anthem. American poets, writers, and novelists write their pieces in such a way that every nook and corner of America is loved by one and all. Every American is taught to love his city that is why an American citizen considers himself to be a citizen of thousands of cities. Far-off places of Europe from where his forefathers came to US do not bring any emotion or feeling of belongingness. He feels that his livelihood and daily life depends on American soil and that he only belongs to America. He strives day and night to promote the state or his city where he lives and all this is taking place through schools, colleges, newspapers, magazines and television. It is the crying need of the hour that our education system should consciously promote this vital feeling of belongingness.

My second request to you is concerning the education and promotion of science and technology. India and Pakistan are economically backward countries; here an average person earns seventy dollars a year. In contrast an American earns fifty times more, while a person in England earns twenty times more, in Japan fifteen times, in Iran eight times, in Turkey eight times, and in Iraq, Algeria, Syria and Egypt six times more. My question to you is: Why are we poor as a nation? I totally agree that our national wealth was stolen by the British during their rule over our areas. The question arises, how did we become British slaves?

If the British knew the art of sea-travel and we did not, then who taught them this art in the first place? If Robert Clive's flint lock rifles and guns had a greater craftsmanship than those of the Muslim King Siraj-ud-Daula, then may I ask who taught the British this art of making superior guns? Did they not invent this art themselves, and having invented it, did they not master it through education in their country?

In the famous battle of Panipat, the great Muslim conqueror Babar, won the day due to his use of superior Roman guns. The Turks developed these guns in more sophisticated ways after its invention in 1526; however, Emperor Babar's children did not care to introduce any sort of an institution in India that would have developed this art even further. If you happen to visit Constantinople (now Istanbul), you will find that the Turkish idea of a mosque was that on one side of the building would be a hospital and a school (or madrassah) on the other. This madrassah or place of learning was not to be for the purpose of teaching religious education alone but rather to teach the art of gun-making as well. Unfortunately, those Turks who came to India were not interested in promoting education and learning. They have left behind as their legacy, splendid mausoleums and graves as a reminder, but, alas, no schools or places of learning for people of the Indian continent.

Let me ask you this: if God Almighty has bestowed the American people with plenty of food and a vast continent, then is it not due to their sheer determination that brought them to an unknown land across the oceans? If the Japanese industry has gained worldwide reputation, then how much of it is due to their well designed educational system? God's angels do not descend on Japanese to teach them new technology. There was a time when Japanese goods and products were considered to be of inferior quality, but today it is deemed to be of a much superior quality in technical terms. Do you know that British Leyland started to manufacture mini Morris and the next thing, the Japanese produced a car the size of mini Morris but instead of a 1000 c.c. engine it was 600 c.c. with the same amount of engine power. How can it be? Twenty years ago an American, Professor Townes invented the transistor and was awarded a Nobel Prize for his revolutionary invention. To find out the true nature and internal working of the transistor, the Japanese started their work in Tokyo University right away. The Japanese efforts bore fruit in such a short span of time that since then the Japanese are considered to be the masters in the field of electronics. Not only did they rediscover the transistor but they published the secret of the transistor in a magazine so that any Pakistani, Arab, or Iranian may make use of it in case he could develop the transistor technology a little further. These champions of knowledge, who are they anyway? Would you believe that these Japanese are the people who did not know the art of making a horse-shoe? It is said that when American Admiral Perry came to Japan with his armada of ships, the Japanese tried to block his entry into their harbor but the American bombardment forced the Japanese to let Perry's ship enter into the harbor. One night, a horse was stolen from the Admiral's ship and returned the next day. The mystery behind the strange theft was that the Japanese wanted to see the horseshoe as their science of metallurgy had not been developed to a point where they could make a horseshoe in Japan.

In Japan the exam season is considered to be the suicide season for Japanese students as the admission for higher studies depends on the results of matriculation exam. The standard of this exam is so high that none of the school children in any other part of the world sits for such a tough series of exams in physics and chemistry. During the exam period nobody ever leaks the contents of the questionnaires, no one goes on strike, nobody breaks windows of the buildings where these exams are held. The entire nation, parents as well as students, are gripped in this exam frenzy and they all accept the outcome of exams with the usual Japanese style.

During the month of September, I was fortunate to visit the People's Republic of China. A Chinese student enters the Grade 8 (or middle school) at the age of twelve and at seventeen his school career is just about over. These grade eight schools are equivalent to intermediate college in (Indo-Pakistan). Chinese student has to study the following twelve subjects of which none is

elective: Nationalism, Chinese language, two foreign languages (English, Russian or Japanese), Mathematics, Physics, Chemistry, Biology, Agriculture, History, Geography, Arts, Drama, Music, and Workshops.

Every student has to study twelve complete subjects. Chinese educationists have made up their minds that every student must study science as well as arts.

Perhaps, one may surmise that due to compulsory teaching of science, the level of sixteen or seventeen year old students would be lower as opposed to our intermediate level. To find out the truth myself, I attended math and physics classes in a school in China. I was awestruck to find that a barely fourteen year old was learning orders of infinity. In our part of the world we learn orders of infinity at the B.A. level.

The Chinese people are now determined to introduce every new industrial technique in China. Their national life started two years after ours, but their determination and sheer resolve has resulted in the fact that during these forty years they have learned and mastered science of electronics to its fullest. They started iron casting at 40,000 tons a year and now it is equivalent to 200,000 tons a year. They can now manufacture sophisticated machine tools. Every Chinese student spends one day in his school or university workshop in order to practice his craft. The aforementioned school I visited had fourteen to sixteen year old students making transistor components. Another group was bringing the mineral potassium carbonate to its grinding titration and packaging it in bottles for marketing purposes. A group of four students, aged twelve were repairing shoes for the rest of their classmates. One of the girls in the group said that we should look at the windows of the particular room, which were adorned with curtains. The girl said that when they started repairing shoes they were sort of shy and felt repulsive to repairing smelly shoes; to overcome this problem they covered the windows with curtains. Gradually they got used to it and now no one is shy, at all. I believe that it is imperative for our school children to be productive during their school years. In all of China students and teachers from various schools, colleges, and universities spend their summer holidays in factories and at farms in the countryside.

Perhaps you may think that I am exaggerating the situation a bit but believe me that if someone had told me that such a vast country like China is running smoothly like a calm ocean, I would not have believed it either. How can I, however, deny what I have observed there with my own eyes? Not once but three times I have traveled to China. Still, it is not possible for me to believe that nearly 700 million humans can sacrifice their personal interests for the sake of their nation, and besides this they have intertwined their personal self into national self. Every person of that vast land works tirelessly day and night. Their cities were once filled with filth and flies, and in Beijing once, there used to be a thirty foot wide Dragon sea canal right behind the Royal Palace, full of flies and disgusting filth and was, perhaps, not cleaned during the past three hundred years. But now Beijing is one of the cleanest cities and the credit does not go to the sweepers, but it was cleaned by lawyers, teachers, students, politicians and

store-keepers. This job was done by student unions and in fact they were at the forefront of this movement.

It is true that the Chinese system is working in such an efficient manner because it is egalitarian. A Chinese government minister goes to his office on his bike and he will use an official car only when he is to receive a foreign visitor. The effect of this exemplary behavior is that the Chinese nation is willing to sacrifice. However, the fact that the Chinese nation is determined to learn technology has no bearing on the system itself.

While talking about China, I have digressed from my main topic to some degree. I was relating to you that the British people invented and introduced industrial techniques and they have disseminated the same through proper education. If Japan can teach skills to its workers without having natural or other resources, if the Chinese expect from every child to learn some sort of science or skill and will teach others as well, and if all these nations are endeavoring to eradicate poverty through these methods, then is not there a lesson for us?

One might say that poverty itself is a menace because if a man is hungry then he has no time or inclination to develop his mental faculties. In this context I cannot help but relate to you an incident that took place in Germany some forty years ago. In 1948 I was a student at Cambridge University. Germany had lost the war and the entire German nation was feeling the distressing effects of this crushing defeat. The American Control Commission invited students from Cambridge and other European universities to visit Germany and see the plight of the German nation. Around five hundred students from all over Europe arrived in Munich.

Not a single building structure was left intact in the city and it seemed that the inhabitants of Munich were living in pigeon holes. We were to stay in huge tents in a city park. I had learned from someone that a German scholar was looking for me. One day, I met this scholar who was just a human skeleton. He was employed in a German war camp where there were some Punjabi prisoners as well. He learned from these Punjabi soldiers that I had arrived in the city. He was learning the Punjabi language from these soldiers as he was compiling a German-Punjabi dictionary in 1947. The books he had in his possession were *Heer Waris Shah* and an old copy of *Dulla Bhatti* published from Lahore. As he was experiencing difficulty in understanding some verses from these books he decided to meet me so that I could explain to him some of the passages. Unfortunately, those passages were rather difficult for me as well, and consequently I could not be of much help to him. Now think about that incident for a moment. I don't know whether that dictionary was ever published and if it was, then how many people made use of it, but this is a story of knowledge loving people. A nation whose total GNP is knowledge of science, technology and languages. The people of such a great country know that compiling a German-Punjabi dictionary may be fruitless but they will not waste time in

playing cards or going on strikes or watching useless movies. They consider their time during university years to be extremely valuable; they learn and teach others, perhaps there is a great lesson for us.

In this context I would like to relate a story which was told by the great Chinese leader Mao and invariably you will hear this from almost every person in China.

Once upon a time, an old man lived in northern China whose name was Mr. Unlettered. The old man's house faced south and there were two huge mountains Bang and Wang, situated right in front of his house. One day, he suggested to his children that they should start digging these mountains away. His neighbor whose name was Mr. Intelligent said to his foolish neighbor that he knew he was a stupid old man but not this stupid as to remove those mountains by digging away with his hands. The old man replied, "My friend, you are right but remember if I die, then this work will be carried on by my children, when they die, by their children, then when those kids die it will be carried on by their kids and this digging will go on and on and on. These mountains are not going to grow any taller. Every day we dig they are reduced in size and hopefully this menace will be completely removed from the front of the house." On hearing the old man's tale God Almighty sent two angels, who immediately removed those old mountains in no time.

Our society is inflicted with menaces like these two mountains. Try to remove them from your surroundings with patience. God will have mercy on you one day. Do not be afraid if your endeavors don't bear fruit, but keep on doing your job, and God will indeed bless your efforts. ▮

Afterword

Dr. Katepalli R. Sreenivasan
Abdus Salam Research Professor and Director,
The Abdus Salam International Centre for Theoretical Physics,
Trieste, Italy

Professor Abdus Salam makes a dramatic copy for a biography. He was born into a relatively poor family but made good in incredible ways; he was from a poor Asian country with no strong traditions of doing modern science but broke through those barriers by doing great physics and attaining the pinnacle of glory in the western world; he was the conscience of good science in all developing countries; he felt deeply for the lost glory of the Islamic World and agonized over it with untold burden; he created such fine institutions as ICTP and TWAS and provided them with inspiring leadership; he was admired by scientists all over the world. He was extraordinarily colorful as a scientist and a human being and an intellectual of the first order. He lived like a prince but died in agony. In short, he was many wonderful things – all in one lifetime.

It is thus not a surprise that there is an increasing interest in Salam's rich and varied life and accomplishments. The troubled times of today are especially appropriate for taking this interest because here was a person who professed unabashedly to drawing inspiration from the Qur'an but demonstrated without an iota of doubt that this connection did not interfere with his scientific prowess – indeed, in his mind, his religious outlook added to the richness of his science. Here was a person who succeeded more than once, against many odds.

Several people have thus recently expressed interest in writing about Salam or making movies of his life. This renewed interest has led to requests from various potential authors for access to Salam's files and to people who knew him well. I have made all the catalogued material available to all, but must admit to a misgiving for one reason alone: that very few people have demonstrated the ability to view Salam's complex personality sympathetically and in totality, without depriving the posterity of the contradictions of his life and without deifying him, and yet to draw critical lessons from it. My belief is that Salam, who was clearly aware of his special status, would have wanted nothing less. There is no progress otherwise.

Viewed in this background, the present book by Professor Anwar Dil may be regarded as untypical in its purpose. I have had an opportunity to examine the book's contents even as it was under construction, and experienced the commitment that the author had shown for his other projects. I am convinced that you, the reader, will feel similarly about the outcome. The book speaks to Salam's accomplishments with passion but no pretense. I am thus pleased to

have been asked by Professor Dil to write this Afterword. You will see why Salam is one of my heroes and why I am happy to write about him.

Salam's place in physics is described in several places, but it is useful to understand it in his own words. In an undated popular talk given sometime after 1979, Salam described his work as a major milestone in the quest for unification of forces of nature. He first described Newton's role in the unification of celestial and terrestrial gravitation – an idea that is now commonplace, but undoubtedly revolutionary at the time. Then came Einstein's theory of relativity that defined gravitation through the curvature of the space-time manifold. Space and time were never again to be considered in separate terms.

On another branch of unification, Faraday realized that electricity and magnetism were two aspects of the same physical phenomenon, and Maxwell wrote down his beautiful equations describing the theory of electromagnetic radiation.

The next set of forces deals with nuclear structure. The weak force is the second weakest after gravity, responsible for radioactive decay and neutrino interactions. Enrico Fermi understood the basics of weak interactions while studying the decay of radiation. The weak force occurs in the decay of nuclear particles requiring, as learnt later, a change of a quark of one flavor to another. The theory that describes the unified electromagnetic and weak interactions is the Standard Electroweak theory, which, in large part, is the work of Sheldon Glashow, Abdus Salam himself and Steven Weinberg, for which they shared the 1979 Nobel Prize.

The strong force is short-ranged, acting over ranges of order 10^{-13} cm and is responsible for holding together the nuclei of atoms. It is important for both nuclear fission and fusion. Despite existing gaps, there is strong evidence to suggest that a theory that unifies strong forces with electroweak forces is required to make sense of the Universe. Salam played an important role in the development of this part of physics as well.

The quest for unifying all forces including gravity has been the focus of attention in high-energy physics, and one sustained effort is the string theory in its several manifestations. It has come under attack recently for not having yet produced tangible physical results but there is little doubt that it has been a very stimulating construct that may ultimately begin to answer important physics questions.

Within this grand construct Salam placed himself in an important position – and rightly so. He had several abiding technical interests such as renormalizability, non-Abelian gauge theories, and chirality. The importance of the Standard Model, which he helped shape, was realized more completely when Gerard 't Hooft proved its renormalizability in 1972 and the experimental confirmation came about in 1983 at CERN.

Physics has moved on. The recent major experimental developments in cosmology have introduced remarkable changes in the outlook of the Standard

Model of quarks and lepton, and have deeply modified the views prevailing at the time of Abdus Salam. Even a normally conservative person today would say that we are witnessing a turning point. Recent experimental findings, which have led to the 2006 Nobel Prize to John Mather and George Smoot for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation, have introduced an entirely new view of the constituents of the Universe. It appears that the overwhelming majority of our scientific and technological knowledge has been confined so far to about 5% of the Universe related to ordinary matter – both inanimate and living. Determining the nature of the missing 95% of the Universe is amongst the most important problems in modern cosmology and particle physics – something that was unforeseen in Salam's time.

Changes in physics have come from another direction as well. Conviction is growing that reductionism, cornerstone of much of the 20th century physics, has serious limitations of principle despite its enormous successes; that a deductive link does not exist between the finest constituents of matter and phenomena that occur on the human scale; that one needs an equally deep understanding of the so-called emergent phenomena regulated by higher organizing principles; that these organizing principles are equally deep in both content and structure. Perhaps it is too much to say that physics at the turn of the 21st century is undergoing a crisis similar to that at the turn of the last, but there is no doubt that the subject is changing its landscape.

It is sometimes said that every great man has had at least one great idea. Salam may be said to have had two: the electroweak theory and the ICTP. As a physicist and as a human being concerned about poor countries and with scientists from there, Salam was simply admirable. He is one of my heroes, and I am honored to hold a professorship in his name.

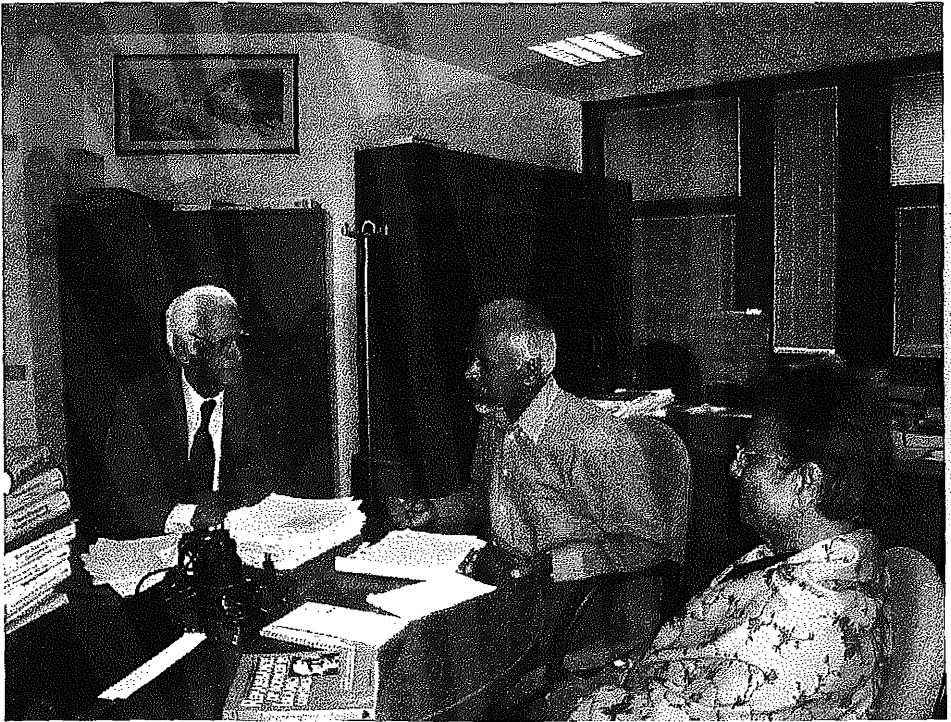
One of Salam's well-known quotes, adopted as one of ICTP's driving mottos, is that "Scientific thought is the common heritage of mankind". In the scientific legacy of our species, many countries and cultures have indeed made crucial contributions – some, no doubt, more than the others. This subject is worthy of deep study and cannot be reduced to clichés. Salam's core concern was that science had become the province of the West in recent three or so centuries, and that the situation needed to be altered if the world as a whole were to share the benefits of science. He particularly bemoaned the fact that science in Islamic countries had fallen into dark times, and, both privately and publicly, cajoled Muslim scientists to change the situation in all possible forms. Unfortunately, his considerations on this score remain valid, by and large, even today.

One should, however, not forget the reasons why the West has been able to gain the ascendancy in science and technology. The West is not innocent in how

it has appropriated a good part of the world's wealth and resources; indeed, there is no doubt that this propensity has played a major role in its recent rise to power and plenty. In so far as it concerns science, however, this pre-eminence lies in its ready acceptance of factual evidence, wherever it may have come from and wherever it may lead to; the courage to make risky hypotheses but the willingness and discipline to subject them to the rigor of experimental verification; a strong focus that does not permit solace to be found in subjective experiences or in the authority of a text. It is not as if the West of yesteryears, or of today for that matter, is flawless in its pursuit of truth – one only has to recall the fate that befell Galileo and the modern-day rise of creationism. Even so, the underlying qualities remain as stated in so far as it concerns the best science that we have inherited. It is the willingness – indeed eagerness – to challenge and be challenged that allows us humans to comprehend the universe and our place in it.

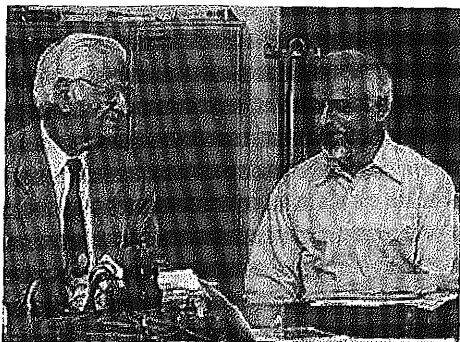
If the rest of the world catches up on these traits, Salam's dream in its best sense will have come true. The institutions he created, namely the ICTP and TWAS, and those of us who have followed the footsteps and tried to fill his large shoes, will be proud to be part of his dream.

Trieste, August 27, 2007

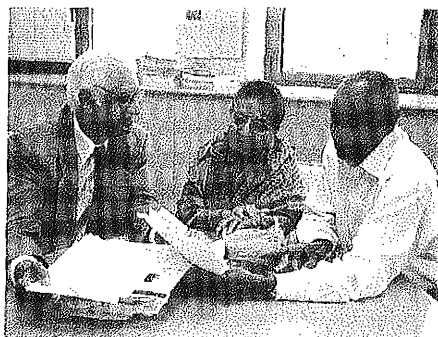


83. Anwar Dil, K.R. Sreenivasan, Afia Dil at ICTP, July 2007

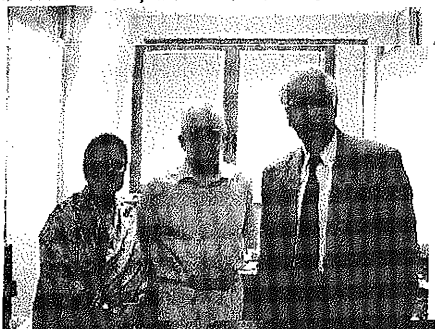
84. Working on Abdus Salam Book at ICTP, Trieste July 2007



a. Anwar Dil, K.R. Sreenivasan



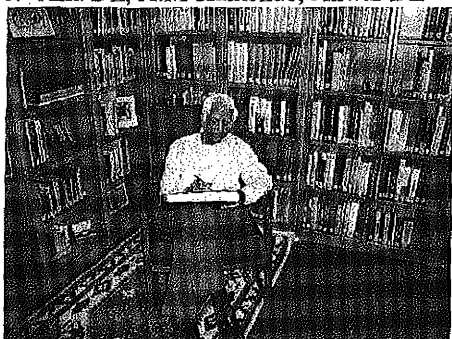
b. Anwar and Afia Dil with M H A Hassan



c. Afia Dil, A.M Hamende, Anwar Dil



d. Jogesh C. Pati, Anwar Dil



e. Working in Abdus Salam Room, ICTP

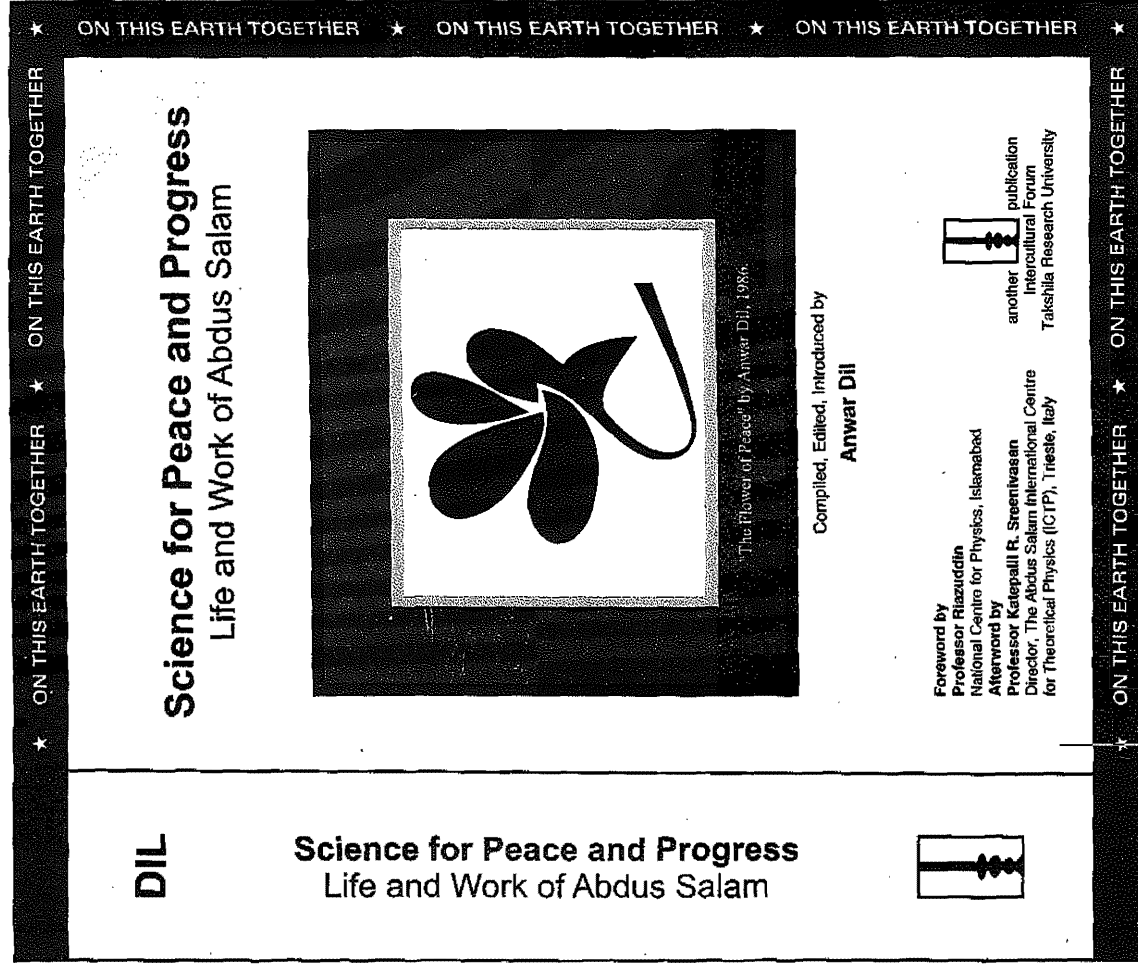


f. ICTP Library



85. New banner of ICTP, November 21, 1997 --

Front Title Cover



Front Inner Flap

It is a great privilege and honor for me to contribute the Foreword to this important book dedicated to the life and work of Professor Abdus Salam. Abdus Salam was one of the profoundest physicists of the 20th century. He not only left a lasting mark in physics but also in the hearts of thousands of physicists, who owed their academic survival and development to the International Centre for Theoretical Physics (ICTP) in Trieste, which is now very appropriately named after him. ... It is indeed gratifying that a research scholar of the stature of Dr. Anwar Dil has undertaken the task of writing books on eminent men of letters and scientists of our time including Norman Borlaug, Raziuddin Siddiqi, M.S. Swaminathan and now Abdus Salam. This indeed is a commendable effort which deserves the highest appreciation and would go a long way to inspire our younger and future generations. The material on Abdus Salam has been immaculately selected, edited, and introduced. I am sure it will bring out that most distinguished aspect of Salam's personality, namely, that he combined scientific excellence with doing social good. ... I recommend this excellent book on Professor Abdus Salam's vision of science and technology for world peace and prosperity to readers and libraries around the world.

Dr. Riazuddin

National Professor and Director General,
National Centre for Physics, Islamabad, 2007

Professor Abdus Salam makes a dramatic copy for a biography. He was born into a relatively poor family but made good in incredible ways; he was from a poor Asian country with no strong traditions of doing modern science but broke through those barriers by doing great physics and attaining the pinnacle of glory in the western world; he was the conscience of good science in all developing countries; he felt deeply for the lost glory of the Islamic World and agonized over it with untold burden; he created such fine institutions as ICTP and TWAS and provided them with inspiring leadership; he was admired by scientists all over the world. He was extraordinarily colorful as a scientist and a human being and an intellectual of the first order.

Dr. K.R. Sreenivasan

Abdus Salam Professor and Director,
ICTP, Trieste, Italy, 2007

Painting on the title page: Detail from "Flower of Peace: Fiftieth Anniversary Tribute to Picasso's Guernica" by Anwar Dil, 1986. 30"x42". India Ink on Handmade Paper.

Back Inner Flap



Abdus Salam (1926-96) was born in Jhang, Punjab Province, British India. He was educated at M.B.S. Middle School and Government College at Jhang; Government College, Lahore where he earned B.A. Honors and M.A. in Mathematics; and Ph.D. in Theoretical Physics from Cambridge University. He had a distinguished career in

teaching, research and administration as Professor and Head of Mathematics Department at Government College and Punjab University, Lahore (1951-54); Lecturer in Mathematics, Cambridge University (1954-56); Professor and Head, Department of Theoretical Physics, Imperial College, London (1957-93); Founder-Director, International Centre for Theoretical Physics, Trieste, Italy (1964-93); Founder-President, Third World Academy of Sciences, Trieste (1983-94); and held several important advisory positions in Pakistan, United Nations, UNESCO, United Nations University and other international scientific organizations and projects. He was the recipient of thirty-six honorary doctorate degrees from around the world; and author of nearly three hundred research papers and several books notably *Iqbal Memorial Lectures: Symmetry Concepts in Modern Physics* (1966), *Ideals and Realities* (1984), *Unification of Fundamental Forces* (1990), *Science and Technology: Challenge for the South* (1992), *Renaissance of Sciences in Islamic Countries* (1994).



Anwar Dil was born in Jullundur, Punjab, and raised in Abbottabad in the North-West Frontier Province. Educated at Government College, Lahore; Islamia College, Peshawar; University

of Peshawar (M.A.); University of Michigan (M.A.); and Indiana University (Ph.D.). He was Professor of Language Science and Communication at United States International University in San Diego, California (1973-2003), and is Professor Emeritus at Alliant International University (2003-). In Pakistan, he served for sixteen years as Lecturer in English Literature at Government College, Dera Ghazi Khan, Sahiwal, and Lahore; and as Professor and Language Specialist at the West Pakistan Education Extension Centre, Lahore. He is the author and editor of over forty books including nineteen volumes in the distinguished Language Science and National Development Series published by Stanford University Press. His internationally acclaimed books, among others, include: *Humans in Universe* (with Buckminster Fuller, 1983), *On This Earth Together* (1994), *Norman Borlaug on World Hunger* (1997), *Science, Education, and Development* (2002), *Toward a Hunger-Free World* (2004). His abstract-calligraphic paintings are in the collections of connoisseurs around the world.

Back Title Cover

★ ON THIS EARTH TOGETHER ★

★ ON THIS EARTH TOGETHER ★

Science/Technology/World Development/Biography



Dr. Salam was an unparalleled leader of science for society. In this respect he resembled Albert Einstein, who once said, "Concern for man himself and his fate must always form the chief interest of all technical endeavors in order that the creation of our minds shall be a blessing and not a curse." Dr. Salam's life and work will continue to inspire generations of young scientists not only in the developing world but all over the world.

I commend Professor Anwar Dil's book because it documents admirably the development of Abdus Salam as a socially committed scientist and his exemplary service to scientific progress for human welfare.

Prof. M.S. Swaminathan

President, Pugwash Conferences on Science and World Affairs;
Chairman, M.S. Swaminathan Research Foundation, Chennai, India, 2007

Abdus Salam was one of the great spirits of our time, great as a scientist, greater as an organizer, greatest as the voice of conscience speaking for the advancement of science among the poorer two thirds of mankind. I met him first in England when he was twenty-four, a student recently arrived from the turmoil of newly independent Pakistan. I was then supposed to be a leading expert on the theory of quantum electrodynamics. I quickly found out that Salam knew as much about that subject as I did. He asked me for a topic for his research. I gave him the topic of overlapping divergences, a highly technical problem that had defeated me for two years. He solved it in a few months.

Prof. Freeman J. Dyson

Professor, Institute of Advanced Study, Princeton, USA, 1999

Abdus Salam's life was gentle, and the elements so mixed in him that Nature might stand up and say to the world: "This was a man!"

Prof. Sheldon L. Glashow

1979 Nobel Physics Laureate, Harvard University, 1996

The South Commission Report would have been very different and much less useful without his contributions.

President Julius Nyerere

Chairman of South Commission, Former President of Tanzania, 1996

Professor Salam will forever be remembered as a man of exceptional achievement and human qualities.

Dr. Federico Mayor, Director General, UNESCO, Paris, 1996

He was also deeply concerned about the proliferation of nuclear weapons and served on many high-level committees involved in the promotion of international peace and collaboration and in the development of peaceful uses of atomic energy.

The Times, London, November 26, 1996

Most of the scientific effort in Pakistan is in a large measure due to Professor Salam's imagination and the weight of his personality. Salam is a symbol of the pride and prestige of our nation in the world of science.

Dr. I.H. Usmani

Chairman, Pakistan Atomic Energy Commission, 1967



Intercultural Forum

San Diego, California • Islamabad, Pakistan

★ ON THIS EARTH TOGETHER ★

★ ON THIS EARTH TOGETHER ★

Index

- Africa, Science in, 523, 567
 Drought, Desertification, and
 Food Deficit Study Project, 299,
 301
 Al-Asuli, 91, 100, 297-98, 441
 Al-Biruni, 64, 106, 200-01, 227, 325,
 335-36
 Al-Ghazzali, 232-33
 Al-Haitham (See Ibn Al-Haitham)
 Al-Kindi, 184
 Al-Mansur, Caliph, International
 scientific conference and
 founding of Baitul Hikmat at
 Baghdad, 141-42
 Al-Razi, 336-37
 Alien species invasion, 408, 410,
 411-12
 All-Pakistan Science Conference,
 Dhaka, 78-86
 Andreotti, G., 465-66, 485, 486, 564
 Armaments and arms reduction, 181,
 216, 288, 387, 515
 Atoms for Peace Conference 1995,
 Geneva, 413
 Averroes (Ibn Rushd), 223, 240
 Avicenna [see Ibn Sina]
 Baghdad, new capital of the
 Abbasides, International
 scientific conference at, 141
 Barbers (See Hairdressers)
 Beam Weapons in space, 258-65
 Beg, Ulugh, 132, 184
 Beauty, sense of, 565
 Bernal, J.D., 48
 Bethe, Hans A., 117, 536
 Bhopal accident, 313
 Biology, 109, 190, 236, 295, 309, 340
 Biotechnology, 217, 236, 243, 245,
 308-310, 340
 Biosphere, 255, 289
 Blackett, P.M.S., 78, 92, 216, 300,
 430-31, 503
 Blix, Hans, 72, 313, 473, 587-89
 Bohr, Niels, 437
 Brandt, Willie, 249, 253
 Britain, 79
 Bronowski, Jacob, 101
 Brown, Harrison, 152-53
 Budinich, Paolo, 128, 149, 465
 Building great world society, 252
 Bulgaria, Science in, 574
 Canada, 214
 CERN (European Centre for Nuclear
 Research), 44, 276, 307, 389,
 545-46, 615-16
 Chemistry, 109
 Chernobyl, 313, 315
 Chile, Science in, 414
 China, 50, 430, 645-46, 647-48
 Churchill, Winston, 637-38
 Climate studies and change, 95, 443-
 44
 Cold War, The, 248
 COMSATS, 37, 530, 594
 Copernican Revolution, 621
 Copernicus, 208
 Cosmology, 201, 239, 240
 Curie, Marie, 598
 Developing nations/world, 104, 140,
 173-74, 214-16, 250-51
 Development of the South, 371-89
 Dil, Anwar, 27, 29-74, 77, 649
 Dirac, P.A.M., 33, 35, 63, 66, 101-02,
 100, 114-16, 120, 201, 282-83,
 306, 399, 432, 437, 468, 486,
 534, 621
 Disarmament, 93, 252, 284-93, 318,
 515, 516
 Diseases of the Rich and Diseases of
 the Poor, 91-93, 100, 295, 297,
 442
 Disparate distribution of world
 resources, 251-52, 598
 Divided World, 598
 Donne, John, 151, 257
 Dyson, Freeman, 44, 64, 278-80, 410,
 470, 540, 578, 617-19
 Economic aid (See Foreign aid)
 Economic growth, skills and capital
 growth, 79, 80, 81, 83, 372
 role of science and technology,
 376, 480-81
 Economic interdependence, 215, 250

- Education, 84, 85, 96, 97, 139, 214-20, 229, 287, 310-11, 342-44, 346, 350-57, 404-05, 427, 445, 451, 480, 564, 591, 643-46
- Einstein, Albert, 34, 63, 64, 65, 66, 87, 88, 103, 112-13, 115, 117, 184, 185, 199, 201-02, 204-05, 208-10, 282, 295, 326-28, 412, 434, 453, 458, 493, 496, 504, 514, 565, 607, 623
- Eklund, Sigvard, 128, 131, 148-49, 433, 488
- Elementary Particle Physics, 114, 129, 190, 509
- Environment, Global, 166, 289-90, 443
- European Organization for Nuclear Research (See CERN)
- Faiz, Faiz Ahmed, 126, 426, 451, 516, 565
- Faraday, Michael, 65, 109, 201, 210, 234, 236, 421
- Fermi, Enrico, 87, 235, 281, 348, 620
- Fertilizers, 82, 96, 175, 270, 333, 376, 387, 410, 470, 600
- Feynman, R.P., 185, 278, 282, 283, 469
- Forces of Nature, 63, 64, 67, 101-03, 118, 122, 184, 193-94, 201, 204, 236-37, 311, 331, 421, 448, 453, 491, 494, 514, 539, 620, 621
- Foreign aid, 83, 99, 179, 215, 218, 248-49, 250, 267
- Fundamental forces of Nature, Unification of, 193-94, 109-15
- Fundamental Particles, Fundamental Forces, and Gauge Unification, 184
- Galileo, 64, 111, 200-01, 239-40, 620
- Gauge ideas, 185, 211, 212-458
- Gell-Mann, Murray, 122, 281, 411, 533
- Germany, 631-35, 647
- Ghana, Science in, 567-68
- Glashow, Sheldon L., 50, 237, 542-45, 493
- Global vision, 249, 257, 444
- Great Divide between rich and poor, 444
- Between North and South, 441
- God's design, 78
- Gondisapur, 142, 143, 145, 147
- Gravitational force, 101, 123-26, 188, 200, 209
- Green Revolution, The, 376-77, 388
- Gulf University, 231, 242
- Hairdressers, 627-31
- Hammarskjöld, Dag, 176-77
- Haroun-ur-Rashid, 451
- Hassan, M.H.A., 69, 447-52, 476, 479, 592-95
- Hawking, Stephen, 330-31, 494, 533
- Heisenberg, Werner Karl, 201, 212, 295-97, 437, 531
- Hiroshima, 296, 313
- Hoyle, Fred, 410, 432
- Hubble, Edwin P., 65
- Human development, the balance sheet of, 265, 487, 590
- Ibn Khaldun, 144-45, 154-55, 195
- Ibn al-Haitham (Al-Hazen), 227, 241, 325
- Ibn Rushd (See Averroes)
- Ibn Sina, 106, 241, 337
- Ideals and Realities, 172-82
- India, 94, 142, 174, 291, 325, 344, 355, 390, 431, 519, 522, 623
- International Atomic Energy Agency (IAEA), 87, 127, 154, 177, 235, 274, 462, 473, 488, 518, 588
- International Centre for Theoretical Physics (ICTP, renamed Abdus Salam International Centre for Theoretical Physics in 1997), 40-41, 127, 129, 148-49, 157, 169, 178, 224-25, 274-77, 391-94, 441, 448, 462-63, 465-67, 472, 475, 482-83, 491, 533-34, 541, 550-54, 555, 562-64, 569-70, 582-83, 585, 588, 592, 601, 613; Italy's support, 130, 178, 275, 465, 472, 587; the idea of setting up ICTP, 40-41, 87-90, 127-135, 177-78, 487-92; Importance for Eastern Europe, 575

- International Commission on Food and Peace, 623-24
- International Commons, 248-55, 257
- International Foundation for Science, 219-20
- International Rice Research Institute (IRRI), The Philippines, 145-46, 427
- International Wheat and Maize Institute, Mexico (CIMMYT), 145-46, 427
- Iqbal, Muhammad, 5, 39, 73-74, 531, 626
- Iran, 79, scientific heritage of, 334; Iran and Islamic countries, development of science and higher technology, 229-34, 286, 334-60, 518, 519
- Islamic Commonwealth of Science, 226, 228-29, 231, 241-42, 449-50
- Islamic Science Foundation, 37, 149, 159-62, 246-47, 449, 511
- Islamic world, Science and technology in, 159-62, 230, 232, 241-42, 246-47, 302-04, 311, 368, 448, 451, 605
- Italy, 149, 178, 269, 274, 393, 407, 473, 561, 564, 614
- Jai Singh, Maharaja, 184
- Japan, 79, 80, 81, 84-85, 241, 304, 306, 308, 341-42, 350, 389-90, 405, 411, 428, 442, 460, 541, 553, 590, 644-45, 646
- Johnson, President Lyndon, 252
- Kemmer, Nicholas, 278, 361, 468-71
- Kenya, Science in, 355, 386, 428-29
- Kepler, Johannes, 208
- Keynes, J.M., 83, 180, 248, 249, 250,
- Kibble, T., 68, 361, 497, 501, 533, 535, 536, 540, 544
- Khan, Muhammad Ayub, 98
- Kissinger, Henry, 173, 269
- Knowledge, 78, 80, 96, 100, 116, 126, 132, 142, 155, 160, 165, 166, 184, 186-87, 194, 196, 206, 222, 226, 243, 252, 309, 310, 324, 326, 364, 375, 425, 442, 500, 515, 564, 589, 590, 602
- "Knowledge will be acquired wherever it can be found", 430
- Koestler, Arthur, *The Sleepwalkers*, 458
- Korea, 430, 442
- Landau, Lev Davidovic, 398
- Less developed world (See Developing nations/world)
- Lie, Sophus, 121-22
- Maimonides, 69, 364-68
- Makhuba, Lydia, 70, 595-96
- Marshall Plan, 249
- Massachusetts Institute of Technology (MIT), 261, 306, 399
- Mathematics – a poetic language, 101-03
- Mathematics in science, 101, 213, 311, 574
- Matthews, Paul T., 119-20, 278-80, 281, 470, 572
- Maxwell, James Clerk, 65, 109, 184, 199, 210, 234-35, 362, 453, 458
- Medawar, Peter, 327
- Michael the Scot, 137-38, 143-44, 183-84, 222-23, 375
- Military expenditure, 181, 252, 286-87, 288, 292
- Morocco, 417-19, 639
- Muhammad, Prophet of Islam, 80-81, 142, 195, 232, 486, 547, 640
- Muslim contribution to science and technology, 64, 415, 449
- Nakajima, Masaki, 250; Nakajima's "Dream for Mankind", 255, 272
- Nathiagali Summer College on Physics and Contemporary Needs, Pakistan, 27
- National Centre for Physics Pakistan, 27
- Nature of Matter, 107, 114, 116
- Ne'eman, Yuval, 122, 439-40, 504
- New International Economic Order, 180, 182, 253
- New World Employment Plan, 250
- Newton, Isaac, 64, 94, 201, 208-10
- Nobel Prize for Peace, 515, 531

- Nobel Prize for Physics, 183-91, 433, 435, 436, 442, 447
 Nuclear accident, The ultimate, 313-18
 Nuclear force, 116, 117, 118, 125
 Nuclear problem, 91, 110
 Nuclear security, 284-93
 Nuclear weapons, 284, 443, 515
 Nyerere, Julius, 479, 518, 531, 593
 Omar Khayyam, 446
 One-World concept, 239, 295, 388
 Oppenheimer, J. Robert, 41, 45, 126, 149, 273, 275, 277, 407, 433
 Orwell, George, 104
 Pakistan, 28, 33, 38, 78-86, 94-96, 97-98, 138-39, 146, 153, 172, 174-75, 197, 216, 229, 300, 390, 397, 506, 508, 509-12, 513, 524-25, 529, 531, 599, 602-03, 606, 643-44; agricultural production, 96; poverty, 79; problem of science and technology, 133; salinity and water-logging problem, 93, 95-96; Salam's love of Pakistan, 57-58, 603
 Pakistan Atomic Energy Commission (PAEC), 415, 488, 507, 602
 Pakistan Institute of Nuclear Science and Technology (PINSTECH), 37, 507
 Pakistan Times, The, 397
 Pati, Jogesh, 533, 541, 544
 Pauli, Wolfgang, 35, 361, 397, 399, 411, 432
 Pauling, Linus, 252-53
 Peierls, Rudolf, 278
 Peru, 521
 Physical Sciences, 108, 110, 204, 422
 Physics, 39, 63, 64, 67, 78, 87, 106, 108, 111, 114, 116, 119, 121-22, 190, 207-213, 238, 240, 295, 303, 329, 362, 397, 410-11, 456, 460, 492, 496, 502-04, 543; excellence of life it brings, 273-83, 492
 Physicist and mystic, 78
 Planck, Max, 113, 114
 Poor nations (See Developing nations/world)
 Pope, John Paul II, 239
 Population explosion, 295, 271, 377-78
 Poverty, Hunger and, 26-27, 37-38, 46, 78-79, 80, 91, 105, 152-55, 172, 271, 319-21, 515, 590, 624
 Pugwash Conferences on Science and World Affairs, 50, 515, 623
 Pythagorus, 122
 Quantum Theory, 113, 124, 201, 205, 240, 282, 402, 428, 513
 Qur'an, The, 43, 86, 126, 192, 193, 195-96, 226, 322, 324, 333, 483, 545
 Ramanujan, Srinivasa, 52, 61, 577
 Reagan's Strategic Defense Initiative (SDI), 294-95
 Religiosity, 326, 327, 565
 Revelle, Roger, 93, 98, 216-17, 219, 300, 415
 Riazuddin, Foreword by, 25-28
 Rubbia, Carlo, 475, 545-47
 Russell, Bertrand, 294
 Russia, 80, 235, 317, 398, 413, 463
 Sagan, Carl, 316, 317,
 Sakharov, Andrei, 369-70
 Salam, Abdus,
 Adviser to the Education Commission of Pakistan, 36;
 Article on Ramanujan, 52, 61, 577;
 Biographical profile, 17-24;
 Cambridge University days, 468-71, 578;
 Cavendish Laboratory, 410, 454-55;
 Chief Scientific Adviser to the President of Pakistan, 36;
 Concept of successful life, 77;
 Contribution to Theoretical Physics, 397-101, 401, 403;
 Creation of COMSATS, 72, 529-31;
 Creation of ICTP, 87-90, 548, 552, 553, 562, 566;

- Creation of other centers of scientific research, 587;
 Creation of TWAS, 44-45, 554;
 Decision to become theoretical physicist, 432;
 Director of ICTP, 413-14, 423-24, 426, 488;
 Early life, 29-32, 50-54, 409, 422, 576, 591, 641-43;
 "Equal to several member states [of UN]", 602;
 Fellow at Institute of Advanced Study, Princeton, 34, 401, 432;
 Fellow at St. John's College, 501, 410, 432, 454, 462, 468-71, 534, 540, 579;
 Government College Lahore days, 30-33, 528, 576-77;
 "Great synthesizer of science", 622
 Imperial College London, 54, 502-05, 537-38;
 Member of the Scientific Commission of Pakistan, 415;
 Networking on telephone, 580;
 Nobel Prize for Peace, 612;
 Nobel Prize of Physics 1979, 41-44, 435, 447-48, 455, 462, 465, 545, 563

 Remembrances of Abdus Salam:
 D. Akyeampong, 523, 566-68;
 A. Alam, 513-17;
 A. Ali, 495;
 "A legendary figure among scholars and scientists", 623;
 Atomic Energy Organization of Iran, 518;
 A. Badran, 589-92;
 P.M.S. Blackett, 402;
 H. Blix, 473, 518, 587-88;
 L. Bertocchi, 473-75, 554-57;
 J. Bronowski, 101;
 P. Budinich, 472, 552-54;
 N. Calder, 409-16, 597-99;
 Chinese Academy of Science, 518;
 Dalafi, H.R., 447-52;
 R. Delbourgo, 497-98, 568-71;
 M.J. Duff, 501;
 S.A. Durrani, 528-31;
 F.J. Dyson, 618-20;
 G. Feldman, 571-73;
 L. Fonda, 557-58;
 G. Fonti, 586-87;
 "For him laughter was part of Physics", 579;
 S. Fubini, 564-65;
 G. Ghirardi, 558-60;
 S.L. Glashow, 542-45;
 A.M. Hamende, 562-65;
 M.H.A. Hassan, 476-79, 592-95;
 "His power to persuade", 580, 588;
 "His soul is marching on", 565;
 P. Hoodbhoy, 524-25;
 F. Hussain, 612-13;
 Mian Afzal Hussain, 447;
 M. Kamran, 525-26;
 M.A. Khan, 599-604;
 V. Lattore, 608-11;
 S. Lundqvist, 581-82;
 F. Mack, 573-75;
 S. Mascarenhas, 610-12;
 F. Mayor, 518;
 R. Meidani, 582-86;
 Yuwal Ne'eman, 439-40;
 Julius Nyerere, 519, 531-32;
 A. Papic, 480-81;
 J.C. Pati, 498-99, 541-42;
 Personality of Abdus Salam, 27, 28, 29-32, 42, 51, 55-57, 58, 70, 73-74, 403, 412, 423, 425, 446, 461, 471, 475, 477, 478, 479, 499, 500, 501, 514, 516-17, 524-26, 528, 531, 532, 534, 538, 545, 552-53, 556, 557, 558, 560, 564, 571-73, 576, 584, 603, 612, 649;
 F. Press, 488;
 S. Randjbar-Daemi, 532-34;
 F. Reines, 461;
 I. Saavedra, 608;
 A. Sadiq, 621-22;

- Salam as classfellow and friend,
537-38, 557, 575-79, 600;
- Salam as collaborator, 498, 540,
541;
- Salam as colleague, 499, 500,
505, 540, 543-44, 549-52,
555, 558, 559, 562-65, 608,
611;
- Salam as Director of ICTP, 473,
474, 570-71;
- Salam as teacher, 495, 497, 499,
501, 534-37, 544, 566, 568-69,
615;
- Professor of Mathematics,
Government College, and
Punjab University, Lahore,
401;
- Lecturer in Mathematics,
Cambridge University, 402;
- Professor of Theoretical
Physics at Imperial College,
402, 421, 439-40, 454-55,
497-98, 502-03;
- Salam's address to Pakistani
students, 641-48;
- Salam as scientist, 506-08, 527,
533, 534-35, 541-42, 544, 545-
49, 559, 617-19;
- Salam as short story writer, 629-
31;
- Salam as student, 29-32, 528,
537, 556, 575-78, 613;
- Salam's contribution to
Theoretical Physics, 410-12,
420-21, 433, 454, 475, 524,
561;
- Salam's contribution to world
development, 414, 427, 527;
- Salam's "Cosmic Anger", 596-
98;
- Salam on Germany after World
War II, 631-35;
- Salam's humor, 627-29;
- Salam's influence on other
scientists and nations, 414,
423, 437, 439, 478, 479, 495,
499, 500, 501, 504-05, 507-08,
511, 521, 522, 524, 528, 531,
535-36, 540, 546, 555, 559,
566, 568-69, 574, 596, 608,
611;
- Salam's interest in biology, 575;
- Salam on Zafrulla Khan, 636-40;
- Salam on People's Republic of
China, 645-48;
- G. Salvini, 475-76;
- N. Sharif, 549;
- J. Singh, 491-94;
- C.H.L. Smith, 616-17;
- C.P. Snow, 437-38;
- M.S. Swaminathan, 623-24;
- A. Tavkhelidze, 489;
- "The modern day Einstein", 573;
- Turkish Academy of Sciences,
519;
- University of Jordan, 520;
- United Nations University, 520;
- I.H. Usmani, 415;
- M.A. Virasoro, 548-52;
- S. Weinberg, 495-96;
- "Wise Man" on advising UN on
application of science and
technology, 409;
- A. Zichichi, 496-97;
- J. Ziman, 420-24, 579-81;
- Salam on:
African scientists and concepts of
rhythm and harmony, 407;
- Dirac, P.A.M., 33, 534, 535;
- Economic development, 38, 77-
81, 140, 346, 374, 383, 515,
562;
- Einstein, 432, 460;
- Energy, 425;
- Faith, 484, 546-47;
- Family, 435-36;
- God, 434;
- ICTP, 407, 413-14, 462-64, 465-
67, 472-73, 485, 491-92,
527, 533, 552, 553, 562-63,
570, 574, 580-81, 582-83,
586-89, 613;
- Jewish scientists, 407;
- Maxwell, James Clerk, 433;

- Muslim contribution to science
 and technology, 403, 415, 449;
 Newton, 433;
 Nobel Prize Ceremony, 435, 436,
 545;
 Physics, 62, 433-34, 483, 527;
 Religion, 484, 539, 547;
 Religion and science, 412, 455,
 547;
 Science, 410, 412, 426, 428, 438,
 442-43, 492, 501;
 Science in Islamic world, 448-49,
 450-51;
 Science in Pakistan, 405-07, 547;
 Science in Third World, 448,
 463-64;
 Science transfer before
 technology transfer, 425, 442;
 Sufism, 434;
 Theoretical Physics, 407-08;
 Unifying mankind, 461, 547;
 Unification of all forces of
 Nature, 496-97, 505, 539,
 547, 607, 615;
 United Nations University, 408,
 414;
 "O Lord, work a miracle", 72,
 416;
 "Only Connect", 420;
 Principle of Unity in Nature and
 Mankind, 420;
 Muslim Contribution to science
 and technology, 403;
 Religion, 484, 547;
 Salam's books: Ideals and
 Realities, 436, 441, 446, 555,
 565; Renaissance of Sciences
 in Islamic Countries, 437;
 Science and Technology:
 Challenge for the South, 47-
 48, 519, 532
 Salam-Usmani partnership, 36, 415,
 507
 Salman, Saif-ud-Din, 132
 Sarton, George, 138, 194, 326
 Schrödinger, Erwin, 201
 Science, 43, 64, 66, 85, 92, 86, 190,
 295, 310, 328-31, 442, 450, 451,
 453, 492, 493, 545, 561, 565
 Science and peace, 294-98, 515-16,
 531, 586
 Science and technology in Third
 World, 47, 48, 78, 100, 137, 196,
 238-39, 350-55, 361-63, 371-88,
 442
 Science as common/shared heritage
 of mankind, 190-91, 194-95, 324,
 364-67, 374, 389, 448, 450, 483-
 84, 545, 567, 574, 617
 Science in international development,
 214, 266-72, 355-56, 389-94, 492
 Science in Islamic countries today,
 229-30, 231-32, 341-53, 356-57
 Science is universal, 450
 Science and religion, 326, 459, 472,
 484, 546-47
 Science and technology transfer, 234,
 268-69, 305-06
 Sciences in the Arab-Islamic world,
 226-47, 347-55
 Scientific manpower, measuring of,
 231,
 Scientists as unifiers, 64
 Scientist on ideological matters, 38,
 78, 154, 155
 Scientists in the developing world,
 45, 64, 134, 248-57, 363, 389-94;
 their isolation, 88, 132-35;
 their responsibility, 64, 86, 155,
 295, 363
 Scotland, 84, 85
 Second World War, 390
 Silent Genocide, 319-21
 Snake Theory, 493
 Snow, C.P., 338, 437, 491
 South Commission, 47, 48-49, 372-
 73, 479-80, 519, 531-32, 593
 Soviet Union, 65, 99, 275, 304, 313,
 369, 392, 397, 481
 Spain, Fusion of cultures in, 221-25
 Sreenivasan, K.R., Afterword by,
 649-52
 Sri Lanka, 426, 522

- Stanford Linear Accelerator Center (SLAC), 193, 202
- Supersymmetry, theory of, 282, 499, 504, 533, 536, 607
- Swedish International Development Agency (SIDA), 178
- Syed Ahmad Khan, Sir, 451
- Symmetries, 35, 39, 64, 118, 121-25, 212, 277, 397, 407, 462, 496, 503, 606-07
- Technical education, 96, 97, 84, 354
- Technological revolution, 79, 86
- Technology and attack on poverty, 78
- Technology transfer, 178, 215, 219, 234, 242-43, 268, 305, 340, 342, 378-82, 384-87, 428, 441
- Theoretical Physics, 87, 88, 102, 127, 128, 134-36, 236, 397, 401, 402, 407, 408, 463, 496, 504, 561
- Theory of Everything (TOE), 331-32, 494, 497, 504
- The Times, London, 180-81, 526-27
- Third World, 444
- Third World Academy of Sciences (TWAS), 44-45, 466, 476-79, 553-54, 592-94, 623
- Third World Network of Scientific Organizations (TWNISO), 4679, 593
- Third World Organization for Women in Science (TWOWS), 70, 593, 595-96
- t' Hooft, Gerhard, 456
- Thomson, G.P., 183, 185
- Three-Mile Island, 314, 315
- Toledo and Salerno, The school of, 143, 222-24
- Tomonaga, S., 84
- Trieste, City of Science, 245, 270, 408, 485, 498, 555, 558, 613-14
- Trieste Declaration on Science and Technology for the Development of the South, 372, 389-93
- Tunisia, 639
- Turkey and Islamic world, Science for, 302-312, 430
- Ulugh Beg (See Beg, Ulugh)
- Ummat-ul-Ilm, 242, 245
- UNESCO, 50, 89, 466, 589
- Unifying mankind, 461, 547
- United Nations, 39, 92, 93, 127, 147-48, 151, 154, 158, 163-64, 166-68, 176, 179, 254, 285, 300, 317-18, 355, 582-83, 624
- United Nations Development Program (UNDP), 105
- United Nations University (UNU), 70-71, 127, 148, 160, 163-65, 355, 520, 553
- Universe, Nature of, 107, 113-14, 329-31
- USA, 80, 83, 84, 96, 179, 248, 262, 348
- USSR (See Soviet Union)
- Weak force, 64, 65, 123-25, 189, 202-03
- Weak interaction, 41, 42, 44, 189, 399, 470, 475, 476, 481, 535, 542, 579, 619
- Weapons in Space, 258-65
- Weinberg, Steven, 67, 236, 536, 539
- Weinberg-Salam model, 237, 455-56, 556
- Wells, H.G., War of the Worlds, 258
- Whitehead, Alfred North, 138, 452
- Women in physics and science, 595-96, 598
- Wonder, sense of, 39, 126, 326, 328, 434, 565
- World Institute for Energy, 270
- World University, 150, 151, 156-58, 163-68, 169-70, 541
- World development, 42-43, 98, 100, 178, 265, 273, 277, 284-93, 355-57, 382, 383, 415-16, 561
- World environment, 178, 249, 254, 271, 289-92, 303, 376-77, 444-45
- Yang and Lee, 35-36, 397, 398, 400-01
- Yang-Mill, 458, 500, 533, 543
- Yukawa, Hideki, 88, 102, 117-19
- Zafrulla Khan, Muhammad, 636-41

Science/Technology/World Development/Biography



Dr. Salam was an unparalleled leader of science for society. In this respect he resembled Albert Einstein, who once said, "Concern for man himself and his fate must always form the chief interest of all technical endeavors in order that the creation of our minds shall be a blessing and not a curse." Dr. Salam's life and work will continue to inspire generations of young scientists not only in the developing world but all over the world.

I commend Professor Anwar Dil's book because it documents admirably the development of Abdus Salam as a socially committed scientist and his exemplary service to scientific progress for human welfare.

Prof. M.S. Swaminathan

President, Pugwash Conferences on Science and World Affairs;
Chairman, M.S. Swaminathan Research Foundation, Chennai, India, 2007

Abdus Salam was one of the great spirits of our time, great as a scientist, greater as an organizer, greatest as the voice of conscience speaking for the advancement of science among the poorer two thirds of mankind. I met him first in England when he was twenty-four, a student recently arrived from the turmoil of newly independent Pakistan. I was then supposed to be a leading expert on the theory of quantum electrodynamics. I quickly found out that Salam knew as much about that subject as I did. He asked me for a topic for his research. I gave him the topic of overlapping divergences, a highly technical problem that had defeated me for two years. He solved it in a few months.

Prof. Freeman J. Dyson

Professor, Institute of Advanced Study, Princeton, USA, 1999

Abdus Salam's life was gentle, and the elements so mixed in him that Nature might stand up and say to the world: "This was a man!"

Prof. Sheldon L. Glashow

1979 Nobel Physics Laureate, Harvard University, 1996

The South Commission Report would have been very different and much less useful without his contributions.

President Julius Nyerere

Chairman of South Commission, Former President of Tanzania, 1996

Professor Salam will forever be remembered as a man of exceptional achievement and human qualities.

Dr. Federico Mayor, Director General, UNESCO, Paris, 1996

He was also deeply concerned about the proliferation of nuclear weapons and served on many high-level committees involved in the promotion of international peace and collaboration and in the development of peaceful uses of atomic energy.

The Times, London, November 26, 1996

Most of the scientific effort in Pakistan is in a large measure due to Professor Salam's imagination and the weight of his personality. Salam is a symbol of the pride and prestige of our nation in the world of science.

Dr. I.H. Usmani

Chairman, Pakistan Atomic Energy Commission, 1967



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